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V. Khalaji-Pirbalouty^a; A. Sari^a

^a Department of Biology, Faculty of Science, University of Tehran, Tehran, Iran

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Biogeography of amphipods (Crustacea: Amphipoda: Gammaridae) from the central Zagros Mountains, Iran, with descriptions of two new species

V. KHALAJI-PIRBALOUTY and A. SARI*

Department of Biology, Faculty of Science, University of Tehran, Tehran, Iran

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Seven species of gammarid amphipods were studied in the relatively small province of Charmahal-Va-Bakhteyari in the central Zagros Mountains, Iran. Of these, four are previously known (*Gammarus proietus*, *G. komareki*, *G. syriacus* and *G. balutchi*), one is a new record for the region (*G. pseudosyriacus*) and two are new species (*G. lordeganensis* and *G. bakhteyaricus*). From the taxonomic point of view, head microsculpturing characters were found to be reliable as discriminating sets of characters useful in species identification. Habitat diversification and climatic fluctuations appear to be the main factors for species diversity of the area, and the Zagros Mountains act as a geographical barrier to species distribution.

KEYWORDS: Amphipod biogeography, endemism, new species, *Gammarus lordeganensis*, *Gammarus bakhteyaricus*, SEM, Iran.

Introduction

The widely distributed genus *Gammarus* includes many species which are grouped into five species complexes in the extensive papers by Karaman and Pinkster (1977a, 1977b, 1987) and Stock *et al.* (1998). There are few works on Iranian amphipods, including Karaman (1934), Birstein (1945), Ruffo (1979) and Pesce *et al.* (1982), but in a recent amphipod survey by Stock *et al.* (1998) a large number of specimens were collected from different parts of Iran. Following their work, a series of studies including Yavari (2000), Banakar (2001), Amraii (2001), Khalaji-Pirbalouty (2002), Pourmohammadi-Sarbanani (2002) and Naghib (2002) were started from 1999 in the Department of Zoology, University of Tehran, and on some occasions in collaboration with other universities. The objective of these and ongoing studies were first, to complete sampling, and second, to consider species variations in different provinces as a complementary contribution to the

*To whom correspondence is addressed; e-mail: sari@khayam.ut.ac.ir

knowledge of the Iranian amphipods. The present study is a part of this project in Charmahal-Va-Bakhteyari province in the Karoun and Zayandeh-Roud River drainage basins. This initial study was carried out on amphipods of the province because, compared to other provinces, it has many rivers and streams in a small area (16 533 km²). The main aims were detailed taxonomic survey of the species and their geographical distribution. This resulted in the discovery of two new species and one new record for the Iranian amphipod fauna. Platvoet (1985), Al-Yahya (1991), Elfimov (1995), Grygier (1995) and Sari (1997) discuss the significance of ultrastructural characters in crustacean phylogeny and taxonomy. Scanning electron microscope (SEM) examination of morphological ultrastructural characters of head cuticle of the new species was carried out. These new species were partially described and compared using the ultrastructural data.

Materials and methods

Sampling site

All freshwater amphipods were collected between April 2000 and August 2001 from localities in Charmahal-Va-Bakhteyari province (figure 1; table 1).

Collection techniques

Specimens of all species were collected from aquatic plants or from beneath stones, using a dip net with a mesh of 1 × 1 mm, then washed and cleaned of debris. Cleaned specimens were transferred to suitable jars, to which were added a few drops of ether, to narcotize the specimens, then 70% ethanol was added as a preservative. Specimens of *Gammarus pulex* were caught in Surrey, UK.

Specimens were studied morphologically by dissecting them under a low-power microscope (Wild Heerbrugg M1), using a pair of fine needles. Dissected parts were then studied under a compound microscope (Reichert biovar) and the parts were drawn with the aid of a camera lucida. All specimens were deposited in the Zoological Museum of the University of Tehran (ZUTC).

Scanning electron microscopy

Specimens were washed with agitation in chilled 1% sodium acetate solution for 5 min to remove sediment and debris from the cuticle and appendages. The head and antennae were then dehydrated in a graded acetone series (30, 50, 70, 80, 90 and 100%) according to Haley (1997). Dehydrated parts were air-dried and mounted on stubs with silver adhesive and coated with gold sputter coater (Blazers/SCD004). Gold-coated parts were studied with a scanning electron microscope (Zeiss/DSM960A).

Abbreviations

The following abbreviations are used: A1 and A2, antennae 1 and 2; BP6, basal part of pereopod 6; DA2, details of antenna 2; DCU, dorsal contour of urosomes; EP1–EP3, epimeral plates 1 to 3; GN1 and GN2, gnathopod 1 and 2; H, head; MNDP, mandible palp; OP4, oostegite of pereopod 4; P3–P7, pereopods 3 to 7; PGN1 and PGN2, propodus of gnathopods 1 and 2; PLMX, palp of left maxilla 1; PRMX, palp of right maxilla 1; T, telson; U3, uropod 3.

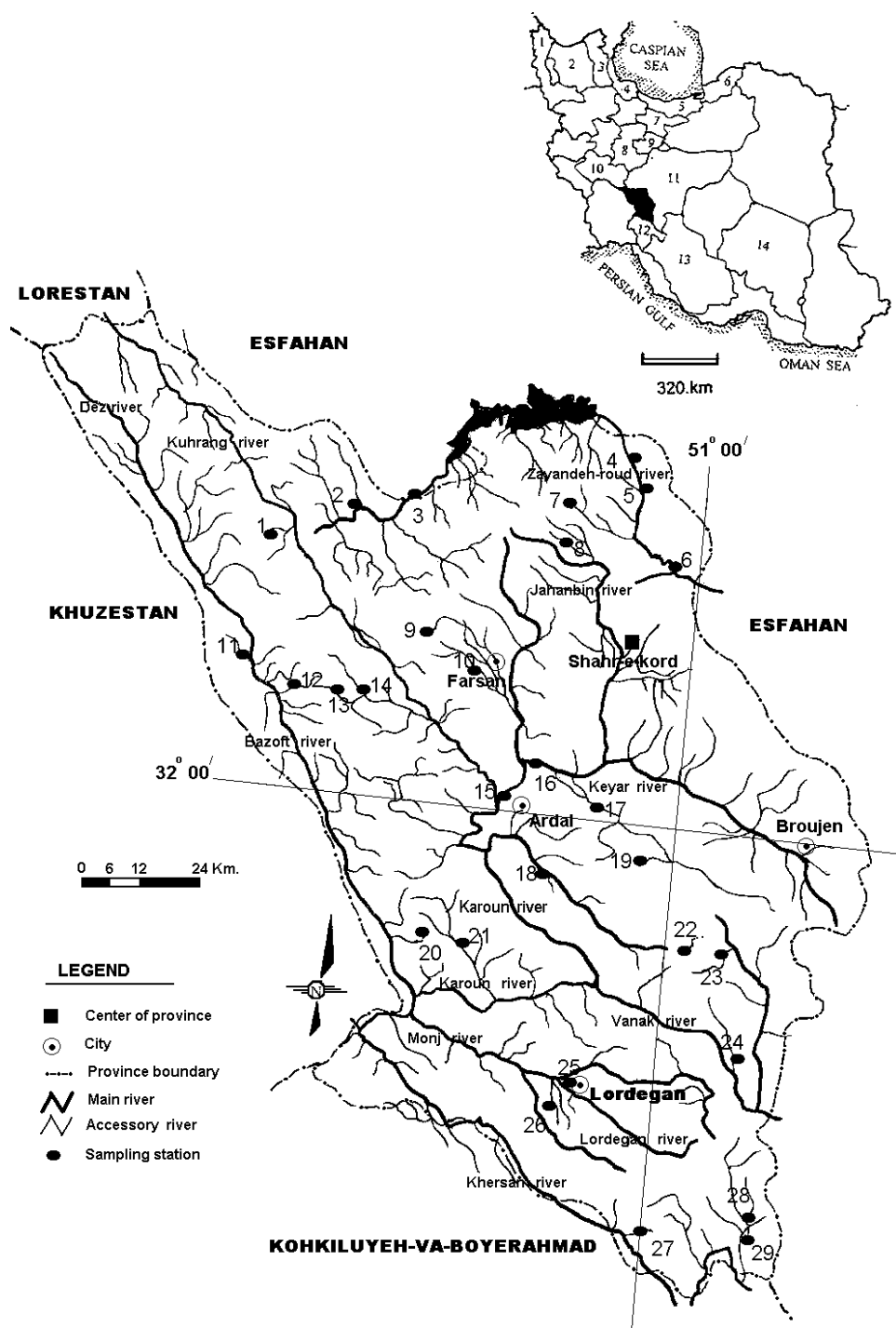


FIG. 1. Map of Chamahal-Va-Bakhteyari province (central Zagros area) and Iranian provinces referred to in the text (see Materials and Methods for location numbering).

Table 1. Species distribution in sampling area.

Site No.	Sampling sites	Location	Species
1	Kouhrang spring	32°28'N, 50°00'E	<i>Gammarus pseudosyriacus</i>
2	Dymeh spring	32°30'N, 50°13'E	<i>G. pseudosyriacus</i> , <i>G. proiectus</i> , <i>G. komareki</i>
3	Sudejan [†]	32°32'N, 50°21'E	<i>G. pseudosyriacus</i> , <i>G. proiectus</i>
4	Markadeh [†]	32°39'N, 50°50'E	<i>G. bakhteyaricus</i> , <i>G. proiectus</i>
5	Hureh [†]	32°34'N, 50°51'E	<i>G. pseudosyriacus</i> , <i>G. proiectus</i>
6	Tchelevan [†]	32°28'N, 50°55'E	<i>G. pseudosyriacus</i> , <i>G. proiectus</i>
7	Gerdab-e-Ben	32°32'N, 50°44'E	<i>G. pseudosyriacus</i>
8	Pir-Balout	32°25'N, 50°40'E	<i>G. pseudosyriacus</i>
9	Sarab-e-Babaheydar	32°18'N, 50°24'E	<i>G. pseudosyriacus</i>
10	Pir-Ghar	32°13'N, 50°33'E	<i>G. pseudosyriacus</i>
11	Arteh spring	32°13'N, 50°01'E	<i>G. pseudosyriacus</i>
12	Mavarz spring	32°09'N, 50°06'E	<i>G. pseudosyriacus</i>
13	Gardaneh-e-Cheri	32°10'N, 50°14'E	<i>G. komareki</i>
14	Doab-Samsami [‡]	32°10'N, 50°18'E	<i>G. pseudosyriacus</i>
15	Behesht-Abad [§]	32°02'N, 50°38'E	<i>G. pseudosyriacus</i>
16	Darkesh-Varkesh [§]	32°06'N, 50°41'E	<i>G. pseudosyriacus</i>
17	Shalamzar spring	32°02'N, 50°49'E	<i>G. pseudosyriacus</i>
18	Deh-Now spring	31°54'N, 50°43'E	<i>G. pseudosyriacus</i>
19	Chaghakhor	31°55'N, 50°55'E	<i>G. bakhteyaricus</i>
20	Shelyle spring	31°49'N, 50°27'E	<i>G. pseudosyriacus</i>
21	Sarkhon spring	31°45'N, 50°33'E	<i>G. pseudosyriacus</i>
22	Beedak spring	31°47'N, 51°06'E	<i>G. syriacus</i>
23	Bizhgerd spring	31°47'N, 51°10'E	<i>G. syriacus</i> , <i>G. bakhteyaricus</i>
24	Gerdebisheh spring	31°34'N, 51°13'E	<i>G. lordeganensis</i>
25	Barm spring	31°30'N, 50°49'E	<i>G. pseudosyriacus</i> , <i>G. lordeganensis</i>
26	Mylase spring	31°28'N, 50°47'E	<i>G. pseudosyriacus</i>
27	Atashgah fall	31°14'N, 51°00'E	<i>G. baloutchi</i>
28	Malkhalifeh spring	31°15'N, 51°16'E	<i>G. pseudosyriacus</i>
29	Sendegan spring	31°13'N, 51°17'E	<i>G. pseudosyriacus</i>

[†]Zayandeh-Roud River.
[‡]Kouhrang River.
[§]Keyar River.

Numbers used for Iranian provinces

The following numbers are used for the Iranian provinces: 1, Azarbayjan-e-Sharghi; 2, Azarbayjan-e-Gharbi; 3, Ardebil; 4, Gilan; 5, Mazandaran; 6, Golestan; 7, Tehran; 8, Markazi; 9, Qom; 10, Lorestan; 11, Isfahan; 12, Kohkiluyeh-Va-Boyerahmad; 13, Fars; 14, Kerman.

Results

In this study seven species were found, including four previously recorded for the region (Stock *et al.*, 1998; Khalaji-Pirbalouty and Sari, in press), one new record and two new species. Here some remarks are given for all the species, while full descriptions of the new species are presented using both light and scanning electron microscopes.

Gammarus proiectus Stock *et al.*, 1998

This species is similar to the type specimens in the Zoological Museum of Amsterdam (ZMA, Amph.201376, 1991). Geographic distribution of species is

restricted to Zayandeh-Roud River basin (figure 1; table 1) as a sympatric species with *G. pseudosyriacus*.

***Gammarus komareki* Schäferna, 1922**

Specimens from Chaharmahal-Va-Bakhteyari province were compared with the material deposited in the ZMA, and some variations for all the examined material are given below.

- Specimens from Chaharmahal-Va-Bakhteyari province have six robust tooth-like setae+one long robust setae+one simple seta (6+1+1) in the terminal armature of the right palp of the first maxilla and one or two simple setae on the lateral margin of the second article.
- Specimens from Turkey (ZMA, Amph.104328, 1970) and from Lorestan province, Iran (ZMA, Amph.202084, 1995) have a terminal armature formula of (5+1+1), and lateral margin with one simple seta.
- Specimens from Ukraine (ZMA, Amph.102432, USSR, 1960) have a terminal armature of (5+1+1) and two simple setae on the lateral margin of the palp.
- Some specimens from Golestan province, Iran, have four simple setae on the lateral margin of the palp.
- The third uropod of all examined specimens shows no sign of plumose setae on the outer margin of the exopodite.
- For specimens collected from Dymeh spring (figure 1, site 2), all setae are much longer than this in other examined specimens.

The geographical distribution of the species is restricted to the northern area of the province (figure 1 and table 1, site 2 and 13) at high altitude (>2200 m) and low temperature (<12°C).

***Gammarus syriacus* Chevreux, 1895**

Compared with material from Syria (ZMA, Amph.105255), specimens from Beedak spring (figure 1 and table 1, site 22) and Bizhgerd spring (figure 1 and table 1, site 23) have shorter setae on the sixth and seventh pereopods. In Bizhgerd spring this species was sympatric with *G. bakhteyaricus* sp. nov. Both localities have slow-running water and Beedak spring has dense vegetation of fennel-leaved pondweed (*Potamogeton pectinatus* L.) which *G. syriacus* was living on.

***Gammarus pseudosyriacus* Karaman and Pinkster, 1977**

This is a first record of *G. pseudosyriacus* in Iran. The species was found in several sampling sites (figure 1; table 1). Compared with the loan material from the Zoological Museum of Hamburg (ZMH, K30540, 1970 and ZMH, K30537, 1970, Turkey) and in addition to variation listed in Karaman and Pinkster (1977a), the following are some additional variations found among the Iranian populations.

- Number of robust tooth-like setae on right palp of the first maxilla varies from four to five.
- There are fluctuations in the number of simple setae and short robust setae on the ventral margin of the first to third epimeral plates.
- In the second epimeral plate, the postero-inferior corners vary from

moderately pointed to sharp, and in the third epimeral plate from moderately pointed to very sharp and pointed.

- The inner surface of the basis of sixth and seventh pereopods have one or two and three to five very short fine subangular setae, respectively.
- The relative lengths of endopodite/exopodite of the third uropod varies from one-half to three-quarters.
- There are some variations in the length of the telson lobes and the number of robust and simple setae.

***Gammarus balutchi* sp. nov.** Khalaji-Pirbalouty and Sari, in press

This endemic species is restricted to Atashgah-e-Lordegan fall (figure 1 and table 1, site 27). It is similar to *G. lobifer* Stock *et al.*, 1998 from Fars province, Iran, and *G. duebeni* Liljeborg, 1852 from the UK, but has some marked differences in the lateral cephalic lobe and also in the sculpturing of the head at the ultra-structural level.

***Gammarus lordeganensis* sp. nov.**
(figures 2–4)

Material

One male (holotype), one female (allotype), many paratypes. ZUTC, Amph.2060, Barme-Lordegan spring (31°30'N, 50°49'E), Alt. 1612 m, 14 August 2000.

Description

Male. Body length up to 15 mm. Lateral cephalic lobe bluntly rounded, eyes reniform to oval (figure 2, H).

Antenna 1: longer than antenna 2, article 1 > 2 > 3, armature scanty, flagellum with 23–27 articles, armed with very short simple setae only, accessory flagellum with four to five articles (figure 2, A1).

Antenna 2: with forward pointed gland cone; gland cone tip not reaching end of the third peduncle article; fourth and fifth peduncle articles armed with groups of simple setae (shorter than the diameter of the peduncular article); flagellum with 11–14 articles but never swollen or compressed; setae implanted near top of each article never forming a flag-like brush; from one to five small calceoli present but some variations were found in their arrangement on flagellar articles (figure 2, A2 and DA2).

Mandible palp: third article armed with 30–35 D-setae, five to six E-setae, two groups of B-setae and two groups of A-setae, without C-setae; second article with seven long and 12 short ventral simple setae (figure 2, MNDP).

Maxilla 1: asymmetrical palps; right palp broader than left; terminal armature of right palp includes six robust tooth-like setae, one long robust seta and one fine seta (figure 2, PRMX) and left palp with eight long robust setae and one or two fine setae (figure 2, PLMX).

Gnathopod 1: with wide and rounded coxal plate partially covering the head (figure 3, GN1), palmar margin extremely acute, posterior margin with seven rows of robust setae, palmar angle with four robust setae, mid-palmar robust setae present (figure 3, PGN1).

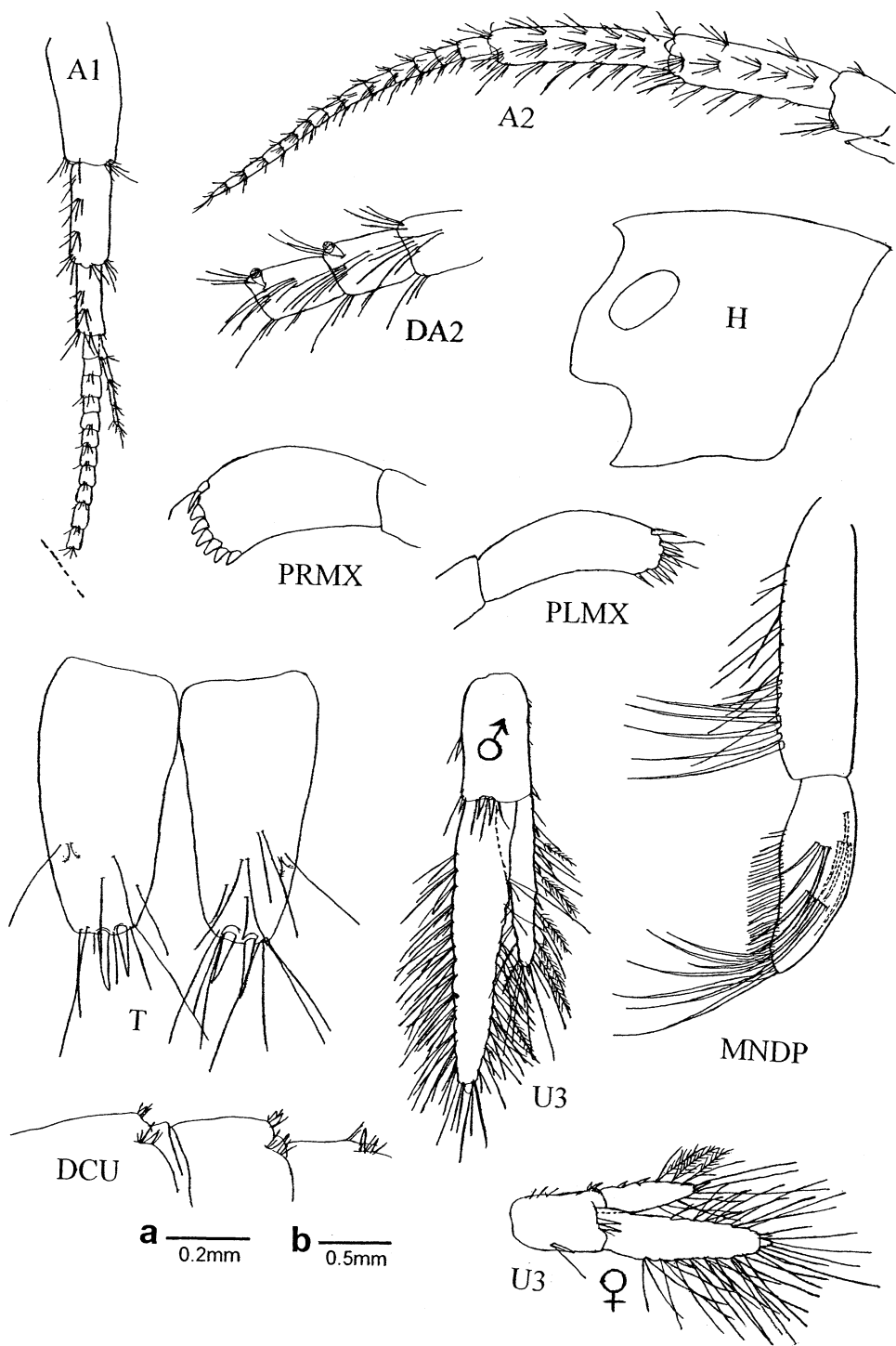


FIG. 2. *Gammarus lordeganensis* sp. nov. Paratype. Scale bars: a (DA2, MNDP, PRMX, PLMX, T); b (A1, A2, DCU, H, U3).

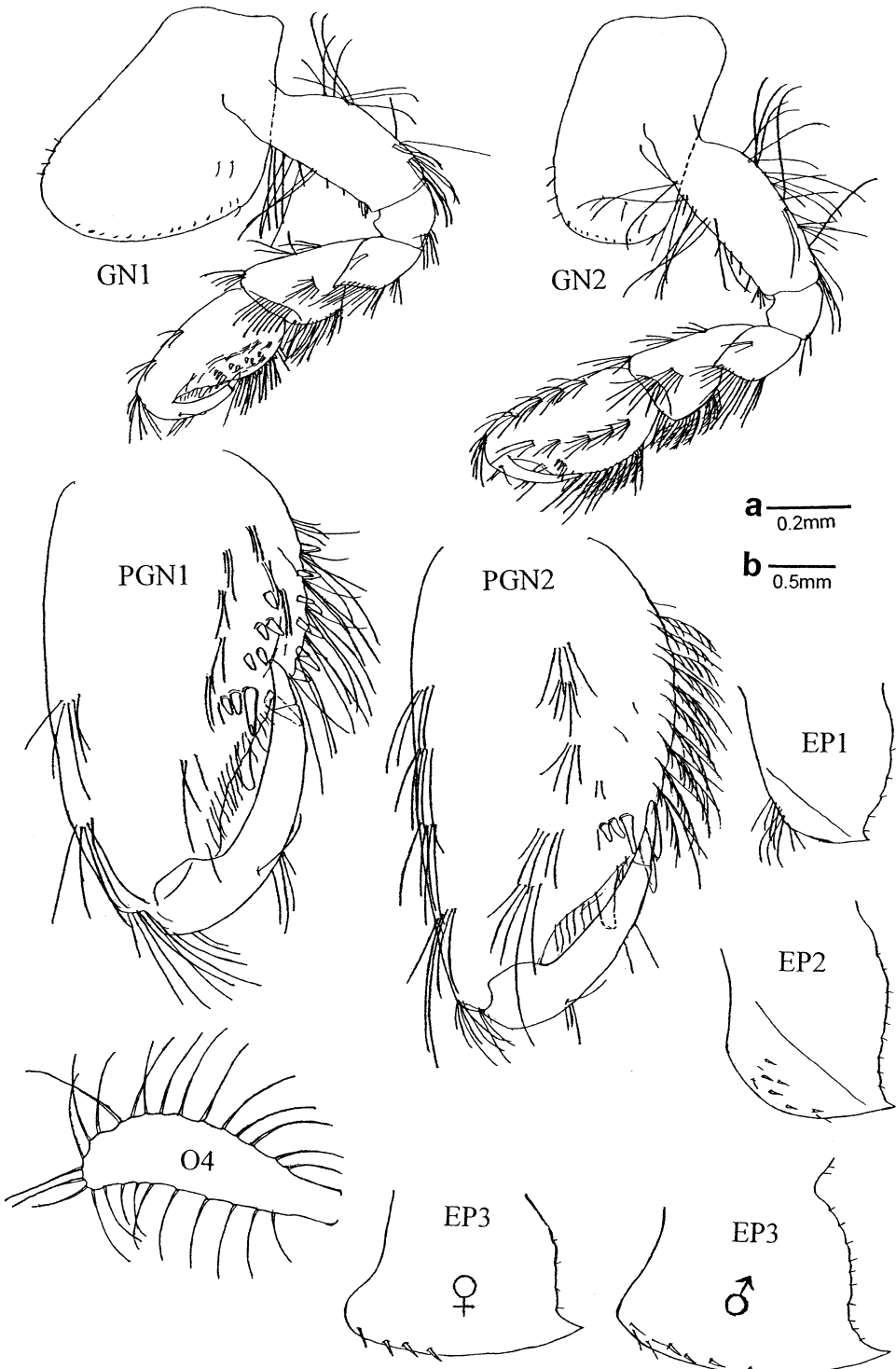


FIG. 3. *Gammarus lordeganensis* sp. nov. Paratype. Scale bars: a (O4, PGN1, PGN2); b (EP1-EP3, GN1, GN2).

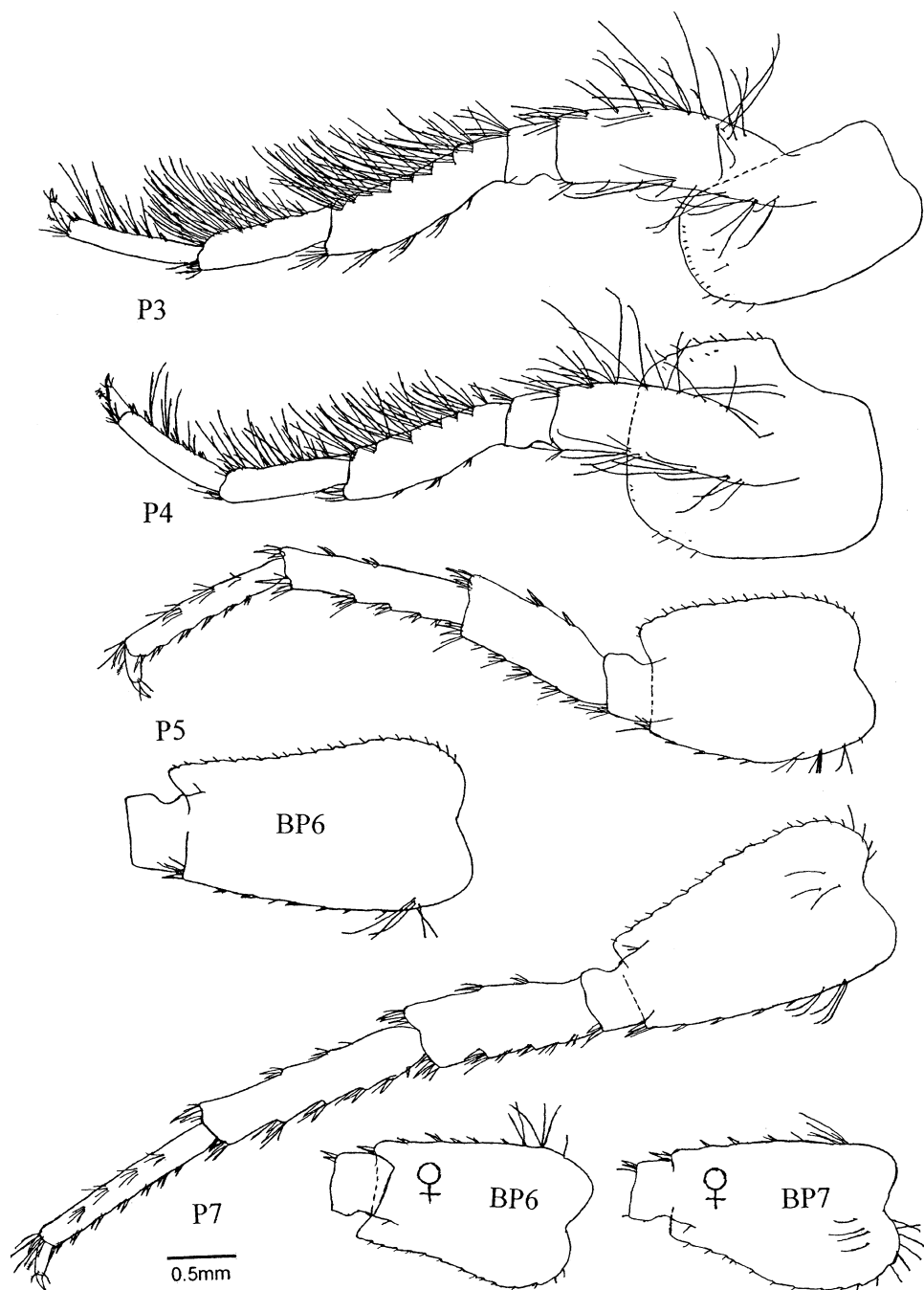


FIG. 4. *Gammarus lordeganensis* sp. nov. Paratype.

Gnathopod 2: with narrow coxal plate; propodus palmar margin sinuous, slightly acute, mid-palmar robust setae present (figure 3, GN2 and PGN2).

Epimeral plates: first epimeral plate slightly pointed (figure 3, EP1), with numerous long simple setae on the anterior margin, second and especially third

plates are acuminate postero-inferiorly; some short simple setae and short robust setae along the inferior margin of second and third epimers (figure 3, EP2 and EP3). Third epimeral plates, lobate antero-inferiorly and convex postero-medially (figure 3, EP3).

Third and fourth pereopod (figure 4, P3 and P4): with long simple setae on posterior margin of merus, carpus and propodus, these are shorter on the fourth pereopod.

Fifth pereopod (figure 4, P5): postero-ventral corner freely produced, posterior margin with 15–20 very short simple setae, merus and carpus with short robust setae (simple setae longer than short robust setae).

Basis of sixth pereopod (figure 4, BP6), with overhanging and well-produced postero-ventral corner and one subangular very short fine seta on inner surface.

Pereopod 7 (figure 4, P7): basis postero-ventral corner rounded and freely produced, with two subangular very short fine setae on inner surface, merus and carpus mainly with simple setae longer than short robust setae.

Urosomites (figure 2, DCU) without obvious dorsal elevation but with poorly developed armature; first and second urosomites armed with groups of two to three mid-dorsal short robust setae and some short simple setae and laterally one or two short robust setae and some short simple setae. Third urosome with some mid-dorsal short simple setae, but with lateral group of two to three short robust setae and some short simple setae.

Uropod 3 (figure 2, U3): second exopodite article minute; endopodite longer than half of the exopodite (about two-thirds); outer margin of exopodite with simple setae, some plumose setae present on both outer and inner margins of the endopodite as well as the inner margin of the exopodite.

Telson (figure 2, T): lobes up to twice as long as width; distal armature with two robust setae and some long simple setae (simple setae up to twice as long as the robust setae); subdistal setae on dorsal surface of each lobe; two pinnulate setae implanted near outer margin of subdistal setae.

Female. Smaller than male; maximum length 13.5 mm; flagellum of first and second antennae with 20–25 and 9–11 articles, respectively; length/width ratio of basis in pereopods 5–7 greater in male (figure 4, BP6 and BP7 ♀).

Oostegite of fourth pereopod as illustrated (figure 3, O4). Compared to third epimeral plate of the male specimens, the female has fewer inferior marginal short robust setae (figure 3, EP3 ♀) but with well-pronounced antero-inferior lobate margin. In contrast to male, third uropod in female is not densely setose, and bears simple setae with a few plumose ones on the outer margin of endopodites (figure 2, U3 ♀).

Remarks

The concluding remarks are based on light microscopic comparison of this species with *G. pseudosyriacus*, *G. syriacus*, *G. lobifer*, *G. proietus*, *G. parthicus* and *G. komareki* from local sampling of the adjacent river basins, and material loans from ZMA and ZMH.

- (1) Second antenna is similar to that of *G. pseudosyriacus*; calceoli present in both species, these are smaller and located on the first five articles in *G. lordeganensis* but larger in *G. pseudosyriacus*, and located on first eight

articles, whereas in *G. lobifer*, *G. proiectus*, *G. parthicus* and *G. komareki* no calceoli are present.

- (2) Right maxillary palp of *G. lordeganensis* with six to seven robust tooth-like setae, which is similar to *G. parthicus*, but four to five in *G. pseudosyriacus*, five in *G. syriacus* and four in *G. lobifer* and *G. proiectus*.
- (3) Coxal plate of first gnathopod much wider than in the other Iranian gammarid species (cf. Stock *et al.*, 1998). This is one of the most discriminating characters of *G. lordeganensis*. The first coxal plate has a dilated lower portion (a feature observed only in *G. laticoxalis*, prior to present study), which forms a forward protruding lobe and covers the postero-lateral area of the lower cephalic lobe.
- (4) *G. proiectus* was named for the produced postero-ventral corner of the basis of pereopods 5–7 but in *G. lordeganensis* only the sixth pereopod has overhanging and well-produced postero-ventral corner.
- (5) In the third uropod, setation is similar to *G. proiectus* on the outer margin of the exopodite, and is non-plumose. There are fewer plumose setae on the inner margin of the exopodite in *G. lordeganensis*, compared to *G. proiectus*. Second article of the exopodite is minute.
- (6) Amongst the most striking characters of this species is the third epimeral plate outline. In both sexes this is markedly lobate on the antero-inferior and convex on the postero-medial margins (figure 3, EP3).

Etymology. Species named *Gammarus lordeganensis* due to its first discovery from Barm spring in the city of Lordegan, Charmahal-Va-Bakhteyari province, Iran.

***Gammarus bakhteyaricus* sp. nov.**
(figures 5–7)

Material

One male (holotype), one female (allotype), many paratypes, ZUTC, Amph.2030, Chaghakhor (31°55'N, 50°55'E), Alt. 2300 m, 6 August 2000. Many specimens, ZUTC, Amph.2031, Bizhgerd spring (31°47'N, 51°10'E), 15 August 2000. Many specimens, ZUTC, Amph.2032, Markadeh village, Zayande-Roud River (32°39'N, 50°50'E), 1 September 2000.

Description

Male. Body length of largest specimen 25 mm. Lateral cephalic lobe truncate (figure 5, H), eyes are reniform to oval, eye diameter less than width of the first peduncle article of antenna 1.

Antenna 1 (figure 5, A1): peduncle article $1 > 2 > 3$, poorly setose, distoventral corner of first peduncular article with three short robust setae, flagellum with up to 40 articles, accessory flagellum with four to five articles.

Antenna 2 (figure 5, A2): gland cone pointed, almost reaching the tip of the third peduncular article, fourth peduncular article shorter than the fifth and armed with some rows of short robust setae and simple setae, but peduncular article five armed with four to five transverse rows of short simple setae. Flagellum with 12–17 articles, armed with short simple setae (as long as diameter of the articles on which

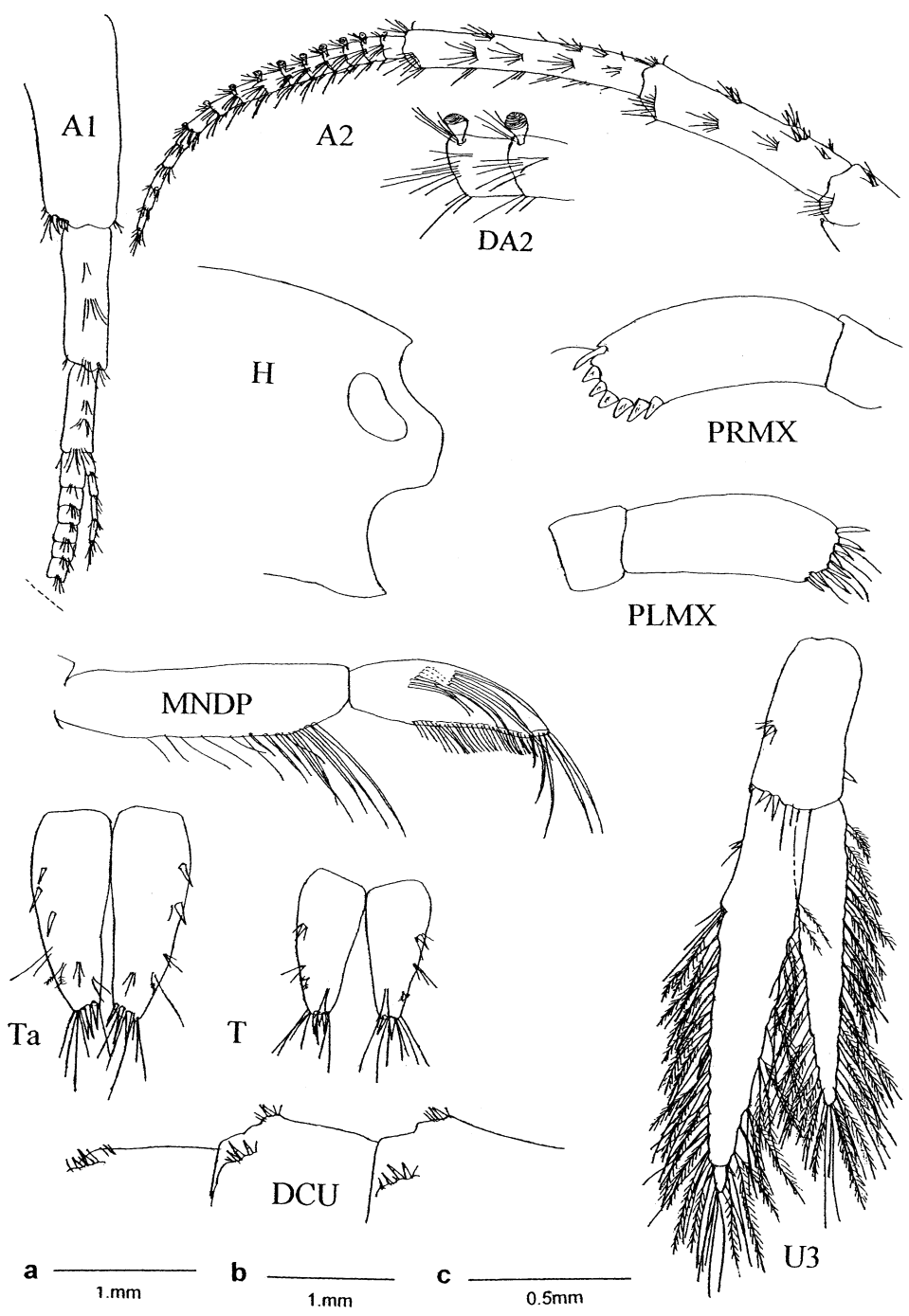


FIG. 5. *Gammarus bakhteyaricus* sp. nov. Paratype. Only Ta from Bizhgerd spring. Scale bars: a (DCU, T, Ta, U3); b (A1, A2, H); c (DA2, MNDP, PLMX, PRMX).

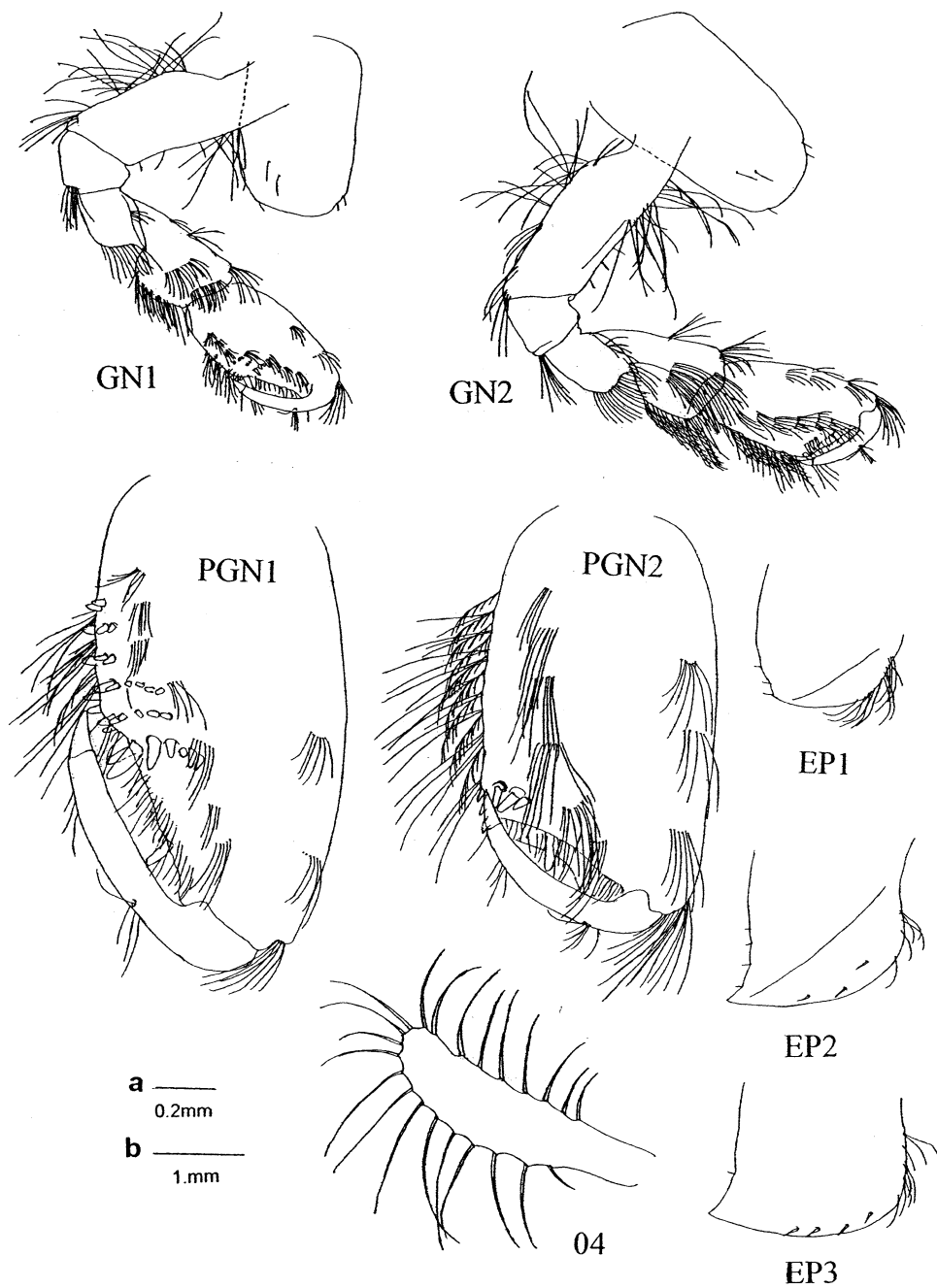


FIG. 6. *Gammarus bakhteyaricus* sp. nov. Paratype. Scale bars: a (PGN1, PGN2); b (EP1–EP3, GN1, GN2, O4).

they are implanted), calceoli can often be found on the first 8–10 articles (figure 5, A2 and DA2).

Mandible palp (figure 5, MNDP): first article unarmed, article 2 with more than 14 long ventral simple setae; third article, with one to two groups of A-setae, two groups of B-setae, no C-setae, a row of 30–35 D-setae and five E-setae.

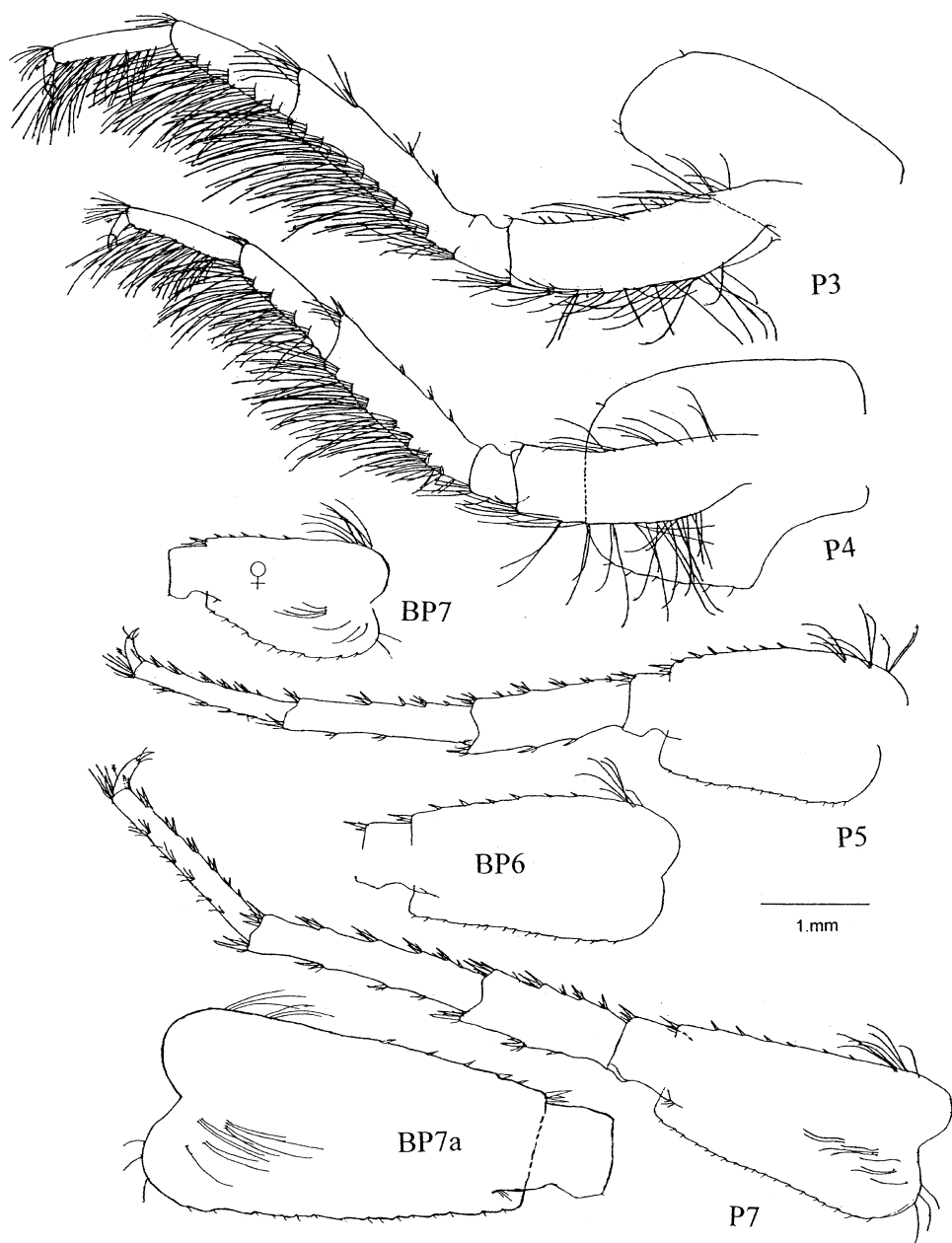


FIG. 7. *Gammarus bakhteyaricus* sp. nov. Paratype. Only BP7a from Bizhgerd spring.

Maxilla 1: palps asymmetric. Left palp (figure 5, PLMX) armed with eight long robust setae and five fine setae; right palp (figure 5, PRMX) broad, armed with five to six robust tooth-like setae, one long robust and one fine setae.

First gnathopod (figure 6, GN1): densely setose, palmar margin (figure 5, PGN1) is extremely acute and armed with six rows of marginal and submarginal robust setae, mid-palmar robust setae present.

Second gnathopod (figure 6, GN2): densely setose, palmar margin transverse,

propodus armed with three palmar angle and submarginal robust setae, mid-palmar robust setae present (figure 6, PGN2).

Third and fourth pereopod (figure 7, P3 and P4): with long simple setae on posterior margin of merus, carpus and propodus (setae are 2.5–3 times as long as the diameter of the articles of the third pereopod and a little shorter in pereopod four).

Fifth pereopod (figure 7, P5): with subrectangular basis, posteroventral corner freely produced, posterior margin with 14–16 very short simple setae, merus and carpus with short robust setae, and simple setae as long as short robust setae.

Basis of sixth pereopod (figure 7, BP6): subrectangular, posterior margin with 14–16 very short simple setae and anterior margin with six very short robust setae.

Seventh pereopod (figure 7, P7): basis margin straight, with varying number of long simple setae on the interior surface, posterior margin with 18–22 very short simple setae; postero-ventral corner rounded, freely produced, with two to four subangular very short fine setae on inner surface; distal articles, with few simple setae between the robust setae. Some specimens with varying number of very short simple setae at posterior and inferior margin of basis (figures 7, BP7 and BP7a).

First epimeral plate (figure 6, EP1): rounded postero-inferior corner, with numerous long simple setae on the anterior margin.

The second and third epimeral plates (figure 6, EP2 and EP3) with sharply pointed postero-inferior corner, numerous long simple setae on the anterior margin and some short robust setae on the ventral margin.

The first two urosomites (figure 5, DCU): well-developed, laterally compressed, dorsal elevations forming humps; dorsal armature consist of dorsomedial and dorsolateral groups of short robust setae and short simple setae.

Third uropod (figure 5, U3): endopodite length about 80% of the exopodite, lateral and medial margin of both endo- and exopodite with numerous plumose and simple setae.

Telson lobes (figure 5, T and Ta) elongate, length always twice or more than width, each lobe with several groups of simple setae and robust setae on outer margin; distal armature includes two to three robust and some simple setae. Two pinnulate setae implanted near outer margin of subdistal setae.

Female. Slightly smaller than male, less setose (especially merus and carpus of third and fourth pereopod, and also third uropod); propodus of gnathopods 1 and 2 much smaller than in male and without mid-palmar robust seta; propodus of first gnathopod with fewer robust setae on posterior margin. Posterior margin of basis in sixth and seventh pereopods (figure 7, BP7 ♀) more convex than in male. Oostegites widest on second gnathopod, gradually narrower on posterior pereopods; fourth oostegite as illustrated (figure 6, O4).

Variability. Except for the normal variability pattern, this species shows variation in the length and armature of the telson lobes (figure 5, T and Ta) and also in the height of the urosomal elevations. In very large specimens the propodus of the gnathopods and the distal articles of the pereopods, and basis of pereopods 6–7, are elongated (figure 7, BP7a).

Remarks

This species has many characters in common with *G. agrarius* G. Karaman, 1973. For example, presence of two to three short robust setae on the distoventral corner of the first peduncular article of the first antenna; fourth peduncular article

of second antenna armed with some robust setae; elongated telson lobes; urosomes with dorsal humps. However, *G. agrarius* has brush-like groups of setae on the ventral side of the flagellum articles of antenna 2 (as in *G. p. pulex* (Linnaeus, 1758)), the palp of right maxilla with two to three lateral margin simple setae (in *G. bakhteyaricus* lateral margin of palp unarmed). Moreover, the lateral cephalic lobes of *G. agrarius* are rectangular and truncate; the propodus of gnathopod 1 has three rows of robust setae on the palmar margin (in *G. bakhteyaricus*, six to seven rows); propodus of gnathopod 2 with six rows of simple setae on anterior margin (in *G. bakhteyaricus* three rows of simple setae); the second and third epimeral plates with sharply pointed hook, as in *G. syriacus*; the endopodite of the third uropod is three-quarters to seven-eighths length of exopodite (in *G. bakhteyaricus* this is less than three-quarters). The oostegites in *G. agrarius* are wider and more densely setose than *G. bakhteyaricus*.

Habitat. This species is common in the semi-running waters, such as spring front pools, on riversides with slow water flow and among the aquatic plants.

Etymology. Species named *Gammarus bakhteyaricus* for its chance discovery in the province of Charmahal-Va-Bakhteyari, Iran.

Comparison of new species using SEM

The lateral cephalic lobe of *G. lordeganensis* is bluntly rounded, the lateral part of the head is partially covered by the wide and round coxal plate of gnathopod 1 (figure 8A). Quadrat in figure 8A shows the area selected for comparison of the head microsculpturing of the new species with *G. p. pulex* from Surrey, UK and *G. agrarius* from Turkey. In all three species the polygon patterns are nearly similar, but in comparison each has a species-specific pore pattern inside the polygons. In *G. lordeganensis* (figure 8B, C) and *G. p. pulex* (figure 8D) pores are distributed within the polygons, and the general pore pattern is sieve-like in both species. The pore numbers in the polygons were about 18–20 and 45–50 per $25\mu\text{m}^2$ for *G. lordeganensis* and *G. bakhteyaricus*, respectively. The pore counts in *G. p. pulex* were as low as 2–3 per $25\mu\text{m}^2$ of head cuticle. But pores are round and partially hooded in *G. lordeganensis* (figure 8C) and have higher frequency in a given area of the head cuticle; also pores are more or less arranged in linear rows. In contrast, pore frequency shows the least density in *G. pulex* with no obvious pore pattern. In *G. bakhteyaricus* (figure 8E) pores are very close together and arranged in a series of nearly parallel interrupted lines. A similar pattern was observed in *G. agrarius* from Turkey but with no interruption in pore lines (figure 8F).

Discussion

Thorough studies of the Iranian amphipods in recent years (Stock *et al.*, 1998; Yavari, 2000; Amraii, 2001; Banakar, 2001; Pourmohammadi-Sarbanani, 2002; Khalaji-Pirbalouty, 2002; Naghib, 2002) have provided much useful information on taxonomy, morphology, ecology, biogeography, reproductive biology and population dynamics. Here, the biodiversity and biogeography of amphipods in the western part of Iran will be discussed. The Charmahal-Va-Bakhteyari province in the centre of the Zagros Mountains is one of the most diverse areas of the region in terms of climate, habitat, fauna and flora. Regarding amphipod fauna, compared with adjacent provinces, currently seven species are reported from this small province (total area 1% of Iran's land area). The whole area is above sea level, ranging from 900 to 4670 m, and mountain peaks are covered with snow

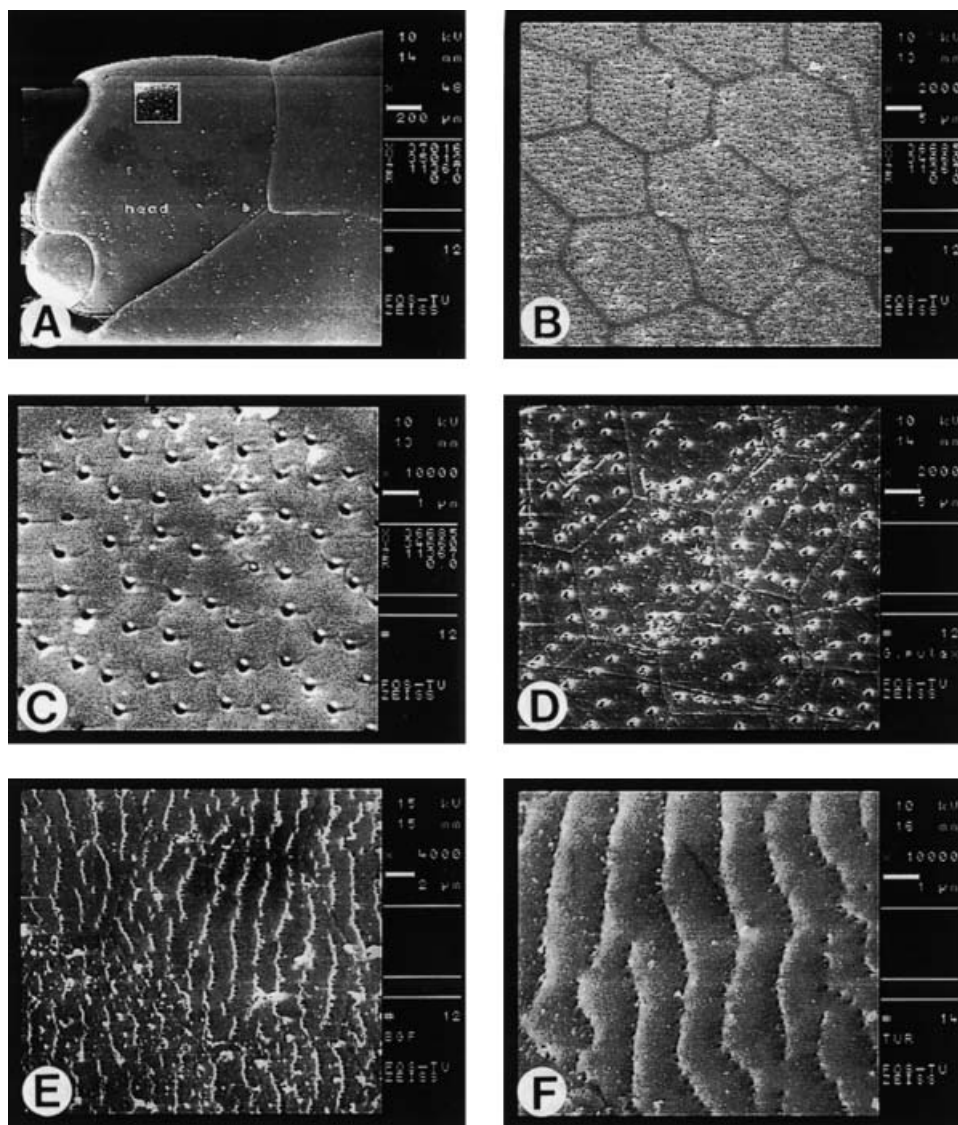


FIG. 8. SEM micrographs of (A) head of *Gammarus lordeganensis*; (B, C) head polygons and pores in *G. lordeganensis*; (D) head pores in *G. pulex* from Surrey, UK; (E) *G. bakhteyaricus* from Bizherd, Iran; (F) *G. agrarius* from Turkey.

throughout the year. Snow is the main source of water, including 1500 springs and 20 rivers within the two river basins of Zayandeh-Roud and Karoon. Of the seven species in the present study, only three were reported in the comprehensive work of Stock *et al.* (1998). Below, each species is briefly considered from the point of view of biogeography and biodiversity.

Gammarus proiactus Stock *et al.*, 1998

This species was first reported from Shazand-Arak (Stock *et al.*, 1998). According to other studies on adjacent provinces (Yavari, 2000; Naghib, 2002), and

also results of the present study, this species seems to be found in the northern regions of the Zagros Mountains. This species was also found further north, in the vicinity of Ghare-Chai River basin (Yavari, 2000). The absence of this species in the river basin of the southern regions of the mountains is indicative of the role of this physical barrier in the geographical distribution of *G. proiectus*. Currently this species is limited to two water basins, Zayandeh-Roud and Ghareh-Chai, and is here considered to be an endemic species.

***Gammarus komareki* Schäferna, 1922**

This species is recorded from Greece, northern Bulgaria, adjacent rivers of the Black Sea, north-west to north-east Iran (map 24 and 29, Barnard and Barnard, 1983), Azerbaijan, northern Turkey (Karaman and Pinkster, 1977a), Sultan-Abad, Ardebil province (recorded as *G. pulex persicus* S. Karaman, 1934) and Sabalan Mountain in Ardebil province (Karaman, 1969). In recent years, this species has been reported from different provinces of Iran including Azarbaijan-Sharghi, Azarbaijan-Gharbi, Ardebil, Golestan, Mazandaran, Lorestan, Kohkiluyeh-Va-Boyerahmad and Fars (Stock *et al.*, 1998), Tehran (Banakar, 2001), Lorestan (Amraii, 2001) and Isfahan (Naghib, 2002). This study shows that this species is well-established in the Alborz and Zagros Mountains, and therefore, it could be referenced as a major component of the Iranian gammarid amphipods. On some occasions it has been found with patchy distribution in the mountains of Isfahan province (Naghib, 2002). Geographically, Iranian populations of *G. komareki* are connected to the European populations through the mountains of north-western Iran and therefore seem to have an Asia Minor origin. From the morphological point of view, all the specimens from different locations in Iran, as well as materials in the ZMA collection, show no sign of plumose setae on the exopod of uropod 3. This is a case of ambiguity caused by its presence only in the description and drawing by Karaman and Pinkster (1977a). It seems there is a need to examine material of *G. komareki* from Europe and Asia to mark possible morphological variations.

***Gammarus syriacus* Chevreux, 1895**

In Iran, this species has been reported before only from Balfees spring (correct name, Belgheis spring), Kohkiluyeh-Va-Boyerahmad province (Stock *et al.*, 1998). In the present study it is reported from two nearby locations in the south-east of Charmahal-Va-Bakhteyari province. According to Barnard and Barnard (1983), this species is found in Syria, Lebanon and from Turkey to Afghanistan. Patchy distribution of *G. syriacus* in Iran could be due to its specific adaptation to the favourable environmental condition of springs.

***Gammarus pseudosyriacus* Karaman and Pinkster, 1977**

This species has been reported from Lebanon and adjacent countries, Turkey and Afghanistan (Karaman and Pinkster, 1977a; Barnard and Barnard, 1983). This is the first record of the species from Iran (Charmahal-Va-Bakhteyari province). Later in the follow-up survey, this species was found by several workers in other provinces including Isfahan (Naghib, 2002) and Kerman (Pourmohammadi-Sarbanani, 2002). Specimens were also found amongst previously unidentified

material collected in 2000 from Markazi province deposited in the ZUTC. These recent reports of *G. pseudosyriacus* from Iran fill the gap between the recorded distribution of species from Turkey and Afghanistan. In the case of *G. pseudosyriacus*, it seems that the Zagros Mountains play a role as a bridge between Turkey and Afghanistan. To our current knowledge, *G. pseudosyriacus* is distributed from the central to the south-east corner of the Zagros Mountains; it has been found to have a patchy distribution in different habitats, with a water temperature range of 5–21°C. Karaman and Pinkster (1977a) reported that *G. pseudosyriacus* has a tolerance to higher temperatures and recorded some specimens in 34°C water temperature. It seems that adaptation of this species to different water temperatures is the main factor for its wider distribution.

The most important result of this study was the discovery of two new species (*Gammarus lordeganensis* and *G. bakhteyaricus*); the geographical distribution of *G. lordeganensis* is limited to two locations (table 1; figure 1). This species was not found in ongoing projects in adjacent provinces. In contrast to the others, *G. lordeganensis*, as an endemic species, is restricted to warmer areas of the province with a mean water temperature of 12°C, including linocene springs and also springs which run to rivers.

In *G. bakhteyaricus*, another endemic species, the most striking character was the body length (max. 25 mm), greater than previously observed in an Iranian amphipod species. This species was found in areas with semi-running water and dense vegetation. Geographical distribution of the species is limited to the northern regions and specific habitats of both Zard-Kooh and Sabz-Kooh Mountains in the central Zagros Mountains.

According to characters given by Karaman and Pinkster (1977a), all the species in the present study belong to the *Gammarus pulex* group. However, recent regular studies on amphipod populations, and thorough examination of their characters, resulted in some ambiguities about species identification. To address these ambiguities, additional, ultrastructural characters were found to be complementary towards proper identification of the species. SEM studies of the head cuticle and its microsculpturing were found to be reliable diagnostic characters at the species level. Studies of head ultrastructural characters in *G. pulex* from Surrey, UK, *G. agrarius* from Turkey, and *G. lordeganensis* and *G. bakhteyaricus* from Charmahal-Va-Bakhteyari province confirmed that these are species-specific characters. These studies of ultrastructure are complementary to recent study (Khalaji-Pirbalouty and Sari, in press) on *G. lobifer* and *G. balutchi* from Iran and *G. duebeni* Liljeborg, 1852 from Cornwall, UK.

The Zagros Mountains have a north-west to south-east direction. This long physical barrier is the main factor separating the two river basins of the area. This has resulted in different aquatic habitats and, probably contributed to the presence of epigeal and hypogean species in the region. In this paper only the epigeal amphipod species are considered.

In summary, some factors such as variety in climate, mountain barriers, and aquatic vegetation and water resources within the river basins provide habitat diversification in the small province of Charmahal-Va-Bakhteyari. Regarding the water resources, these are springs, rivers, small lakes, falls, subterranean waters and a traditional source of water in the dried climate (GHANAT) which brings the water to the surface by serial, connected wells. The higher diversity observed in the species of this province seems to be related to variety of habitats. Zoogeographical

affinities of the amphipod fauna of the present study seem to be categorized as: endemic, Middle-East area and Asia Minor. In this regard, *G. proeictus*, *G. lordeganensis*, *G. bakhteyaricus* and *G. balutchi* are endemic; *G. syriacus* and *G. pseudosyriacus* are Middle-East species and *G. komareki* is considered to be Asia Minor in origin. Fauna and flora of the province show some degrees of endemism: recent studies on lizards (Rastegar-Poyani, 1996, 1998; Rastegar-Poyani and Nilson, 1998; Rastegar-Poyani and Rastegar-Poyani, 2001), fish, *Aphanius vladykovi* (Seifali, personal communication 2002) and flowering plants (Tietz and Zarre, 1994; Zarre and Podlech, 1996, 2001; Zarre, 2000) are examples of similar endemism in other taxa. The Zagros Mountains seem to be a centre of endemism for at least the Iranian amphipod fauna. But, compared to some Zagros plants of the genus *Asteragalus*, which are grouped as palaeoendemic species (Zarre, personal communication 2003), lizards and amphipods could be regarded as recent endemic species. It seems that the Zagros Mountains not only act as a physical barrier for some species, but in some instances provide a refuge for endemic species which are restricted to the lowlands, surrounded by high mountains. In addition to *G. balutchi* (Khalaji-Pirbalouti and Sari, in press), two new endemic species, *G. lordeganensis* and *G. bakhteyaricus*, are reported from such areas.

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