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THE GENUS *HYALOMMA* KOCH, 1844. II. TAXONOMIC STATUS OF *H.* (*EUHYALOMMA*) *ANATOLICUM* KOCH, 1844 AND *H.* (*E.*) *EXCAVATUM* KOCH, 1844 (ACARI, IXODIDAE) WITH REDESCRIPTIONS OF ALL STAGES

РОД *HYALOMMA* KOCH, 1844. II. ТАКСОНОМИЧЕСКИЙ СТАТУС БЛИЗКОРОДСТВЕННЫХ ВИДОВ *H.* (*EUHYALOMMA*) *ANATOLICUM* KOCH, 1844 И *H.* (*E.*) *EXCAVATUM* KOCH, 1844 (ACARI, IXODIDAE) С ПЕРЕОПИСАНИЕМ ВСЕХ ФАЗ ЖИЗНЕННОГО ЦИКЛА

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Key words: *Hyalomma* (*Euhyalomma*) *anatolicum*, *Hyalomma* (*Euhyalomma*) *excavatum*, systematics, adults, nymphs, larvae, species rank
Ключевые слова: *Hyalomma* (*Euhyalomma*) *anatolicum*, *Hyalomma* (*Euhyalomma*) *excavatum*, систематика, половозрелая фаза, нимфы, личинки, видовой ранг

ABSTRACT

Hyalomma (*Euhyalomma*) *anatolicum* Koch, 1844 and *Hyalomma* (*Euhyalomma*) *excavatum* Koch, 1844, previously considered subspecies of *H. anatolicum*, are reinstated as valid species after the examination of numerous specimens of all stages from localities throughout their distribution range. They are clearly distinguishable on existing as well as new diagnostic morphological characters of both their adult and immature stages. Geographic sympatry and peculiarities in their host-parasite relationships further confirm their specific status.

РЕЗЮМЕ

Hyalomma (*Euhyalomma*) *anatolicum* Koch, 1844 и *Hyalomma* (*Euhyalomma*) *excavatum* Koch, 1844, прежде рассматриваемые как подвиды *H. anatolicum*, восстановлены в качестве самостоятельных видов на основании изучения большого числа экземпляров всех фаз развития из многих географических точек. Помимо использовавшихся ранее выявлены новые морфологические признаки, позволяющие безошибочно различать эти виды по всем фазам жизненного цикла. Географическая симпатрия и особенности паразито-хозяинных связей также подтверждают видовой статус обоих таксонов.

INTRODUCTION

The present paper is an up to date English version of a paper previously published in Russian [Apanaskevich, 2003]. The decision to translate that publication was taken for several reasons. First, significant data on the taxonomy of two important *Hyalomma* species are inaccessible to non-Russian speaking acarologists and other specialists in related disciplines. Secondly, it is one of the first critical reviews of the taxonomy of *Hyalomma* species since the works of H. Hoogstraal and B.I. Pomerantsev, both responsible for reorganizing a rather chaotic state of the *Hyalomma* systematics. Furthermore, a number of pronouncements on the taxonomy of *Hyalomma* is debatable or insufficiently substantiated and should be verified. The remake of the publication is also relevant because of the veterinary importance of these ticks in Africa and Asia.

Differentiation between species of *Hyalomma* Koch, 1844, and their taxonomic status at species level are amongst the more difficult problems in the systematics of ixodid ticks. In 1844 Koch described two distinct species, namely *Hyalomma anatolicum* Koch, 1844 and *Hyalomma excavatum* Koch, 1844. Various opinions as to the use of these names surfaced thereafter, of which the views of Hoogstraal and Kaiser [1959] seemed to be the most well founded.

Pomerantsev [1946, 1950] considered *H. anatolicum* and *H. excavatum* as subspecies of the polymorphic species *H. anatolicum*. Based on an examination of a large number of ticks as well as perusal of the type descriptions Hoogstraal and Kaiser [1959] concluded that the names *H. anatoli-*

cum excavatum and *H. anatolicum anatolicum* proposed by Pomerantsev [1946] for the larger and smaller subspecies respectively, are correct and that the converse, despite its common usage in most non-Russian works on ticks, was incorrect.

Hoogstraal and Kaiser [1959] differentiated both males and females of these subspecies on size, colour of the scutum, punctation patterns and grooves on the scutum, shape of male's anal plates and of female's genital structures, and colour of the legs. They also recorded that the hosts of the immature stages of these subspecies are different. Those of *H. a. anatolicum* parasitize large domestic and wild animals, while those of *H. a. excavatum* use hedgehogs, rodents and hares. Furthermore the seasonal occurrences of these ticks in North Africa differ. Nevertheless they still did not exclude the possibility that *H. a. anatolicum* and *H. a. excavatum* could be separate species [Hoogstraal and Kaiser, 1959; Kaiser and Hoogstraal, 1964].

The purpose of the present investigation was to identify distinguishing characters for all stages of these ticks and to arrive at a decision on their taxonomic status. The relevance of this study lies in the important role these ticks play as vectors of *Theileria* spp. to cattle in vast areas of the world.

Based on the records of Pomerantsev [1950], Hoogstraal [1956], Hoogstraal and Kaiser [1959], Kaiser and Hoogstraal [1964], Hoogstraal et al. [1981], Kolonin [1983] and D.A.A's data, as well as unpublished localities at which they have been collected, and making use of their specific identities established in this communication, their geographic distributions are as follows:

H. anatolicum. Africa: Algeria, Djibouti, Egypt, Ethiopia, Libya, Morocco (?), Somalia, Sudan, Tunisia; Asia: Afghanistan, Armenia, Azerbaijan, Bangladesh, Democratic Republic of Yemen, India, Iran, Iraq, Israel, Jordan, Kazakhstan, Kyrgyz, Lebanon, Nepal, Oman, Pakistan, Russia (Dagestan), Saudi Arabia, Syria, Tajikistan, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan and Yemen Arab Republic.

H. excavatum: Africa: Algeria, Djibouti, Egypt, Ethiopia, Kenya (single record, probably introduced), Libya, Mauritania, Morocco, Somalia, Sudan, Tunisia and Western Sahara; Europe: Albania, Greece, Cyprus and Italy; Asia: Afghanistan, Iran, Iraq, Israel, Jordan, Kazakhstan, Lebanon, Saudi Arabia, Syria, Tajikistan, Turkey, Turkmenistan, Uzbekistan and Yemen Arab Republic.

Because of doubtful or incorrect identification it is uncertain as to exactly which of the two species occurs in southern European countries such as Bulgaria, Italy and the countries that constituted the former Yugoslavia. Although D.A.A. has seen only *H. excavatum* in collections from both Greece and Cyprus, this does not exclude the possibility that *H. anatolicum* might also occur there. A more precise study of the distribution of both species in this geographic region is thus indicated. There are also records of *H. anatolicum* from China [Kuofan and Zaijie, 1991] and of *H. excavatum* from Bangladesh [Akhtar and Betschart, 2005] and these should be confirmed.

MATERIALS AND METHODS

Ticks from the collection of the Zoological Institute of the Russian Academy of Sciences (St. Petersburg, Russia), from the United States National Tick Collection (Institute of Arthropodology and Parasitology, Georgia Southern University, Statesboro, USA), from the Museum of Natural History (Humboldt University of Berlin, Berlin, Germany), from the ARC-Onderstepoort Veterinary Institute collection (Onderstepoort, South Africa) and from the collection of I.G.H. (Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, South Africa) were examined.

The immature stages and the finer structures of adults were mounted on glass slides and examined under a light microscope. Macrostructures of males and females were studied under a stereoscopic microscope. Measurements for the female scutum and male conscutum are given in millimeters (mm), and measurements for the immature stages in micrometers (μm). The layout of how the measurements were taken has been illustrated by Apanaskevich [2003, 2006]. The measurements were analyzed using STATISTICA for Windows, version 5.5 on an IBM PC. The following larval characters were used for multidimensional scaling: scutum – length, breadth, ratio length:breadth, length of scutum from posterior margin of eyes to posterior margin of the scutum, ratio breadth of the scutum: length of scutum from posterior margin of eyes to posterior margin of the scutum; breadth of gnathosoma; palpi (segments II and III) – length, ratio length: breadth; hypostome – length; ratio length: breadth; legs – length of genua I. The following characters were used for multidimensional scaling of the nymphs: scutum – the same as for larva; gnathosoma – length, breadth, ratio length: breadth; palpi (segment II) and hyposotome – the same as for larva. Laboratory reared immature

stages and those found in a collection together with adults were used for establishing the morphological characters of these stages.

DESCRIPTIONS

Hyalomma (*Euhyalomma*) *anatolicum* Koch, 1844

The holotype (female, Kleinasien) has been lost [Feldman-Muhsam, 1954; Hoogstraal and Kaiser, 1959], and the neotype (male, Turkey, Iskanderun, abattoir, cattle, 12 August 1954, coll. H. Hoogstraal, M.N. Kaiser) has been designated by Hoogstraal and Kaiser [1959]. This tick has been deposited in the U.S. National Tick Collection (Institute of Arthropodology and Parasitology, Georgia Southern University, Statesboro).

Material examined: approximately 2 500 males, 2 500 females, 1 000 nymphs and 500 larvae collected in Egypt, Sudan, Saudi Arabia, Russia, Armenia, Azerbaijan, Turkey, Iran, Iraq, Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Afghanistan, and India. Both field-collections and laboratory-reared specimens were examined. The neotype has also been studied.

Male (Figs 1, 2a–h)

Conscutum (Fig. 1): length 2.80–4.45 (3.60±0.04, n=94), width 1.60–2.50 (1.99±0.02, n=80), ratio length: width 1.64–2.05 (1.83±0.01, n=80); light, yellow-brown to light red-brown in colour; pale marbling absent; narrowly oval in shape; widest near midlength; cervical and lateral grooves superficial, one third the length of the conscutum; marginal grooves short, approximately 1/4 of the length of the conscutum; posteromedial groove separated from the parma by contiguous punctations or a slight, smooth elevation; caudal field laterally demarcated by modest ridges; both small and large punctations on caudal field; remainder of conscutum sparsely covered by large punctations, which are more dense laterally; fine punctations more or less evenly dispersed over conscutum; parma present or absent; four distinct festoons.

Genital structures (Fig. 2a) as illustrated. *Anal plates* (Fig. 2b): 3 pairs; adanal plates long, narrow, tapering slightly posterior to median projection, lateral margin convex, anteromedial margin concave, with distinct medial projection; subanal shields small, often elongate and tapering, sometimes absent. *Spiracular plate* (Fig. 2c): dorsal prolongation long and clearly separable from body of plate; tail of perforated portion of spiracular plate straight, curving apically. Circumspiracular setae sparse.

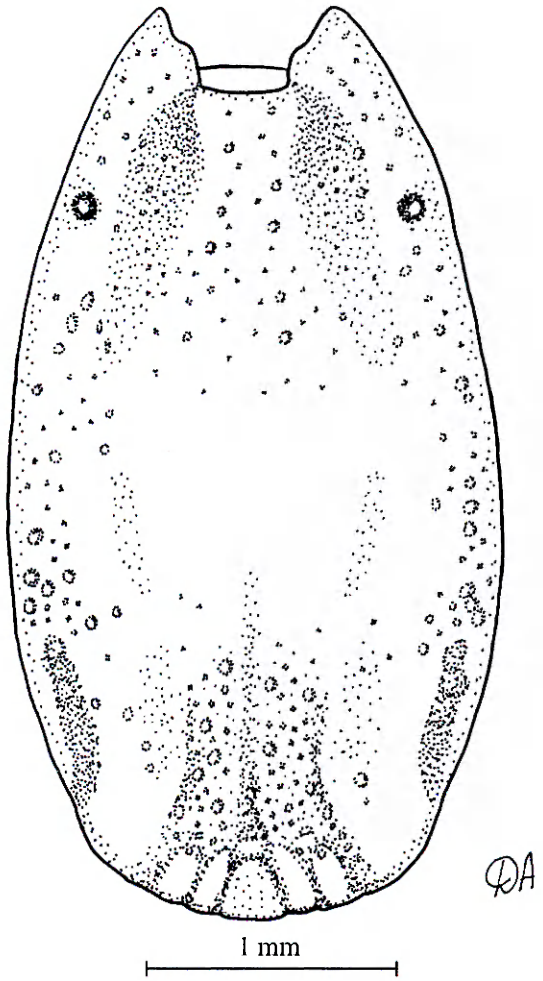


Fig. 1. *Hyalomma anatolicum*, male, conscutum.

Basis capituli (Fig. 2d, e): without lateral projections; dorsal posterior margin straight or slightly concave; with small but distinct cornua. *Palpi* (Fig. 2f): segment I with more than five ventromedial setae. *Hypostome* (Fig. 2g): club-shaped; denticulate portion slightly longer than denticle-free portion (small scale-like projections posterior to last large denticle are not considered denticles).

Coxae (Fig. 2h): posteromedian and posterolateral spurs on coxa I long, close together, tapering to apices; coxae II–IV each with distinct, triangular, posterolateral spur with rounded apex; coxae II and III each with poorly developed, broadly arcuate, posteromedian spur; internal spur on coxa IV distinct, triangular. Ivory coloured enamelling on leg segments indistinct.

Female (Figs 3, 4a–g).

Scutum (Fig. 3): length 1.50–2.20 (1.91±0.01, n=135), width 1.42–2.00 (1.70±0.01, n=135), ratio length: width 1.00–1.20 (1.12±0.005, n=135); light, yellow-brown to red-brown in colour, darker lateral-

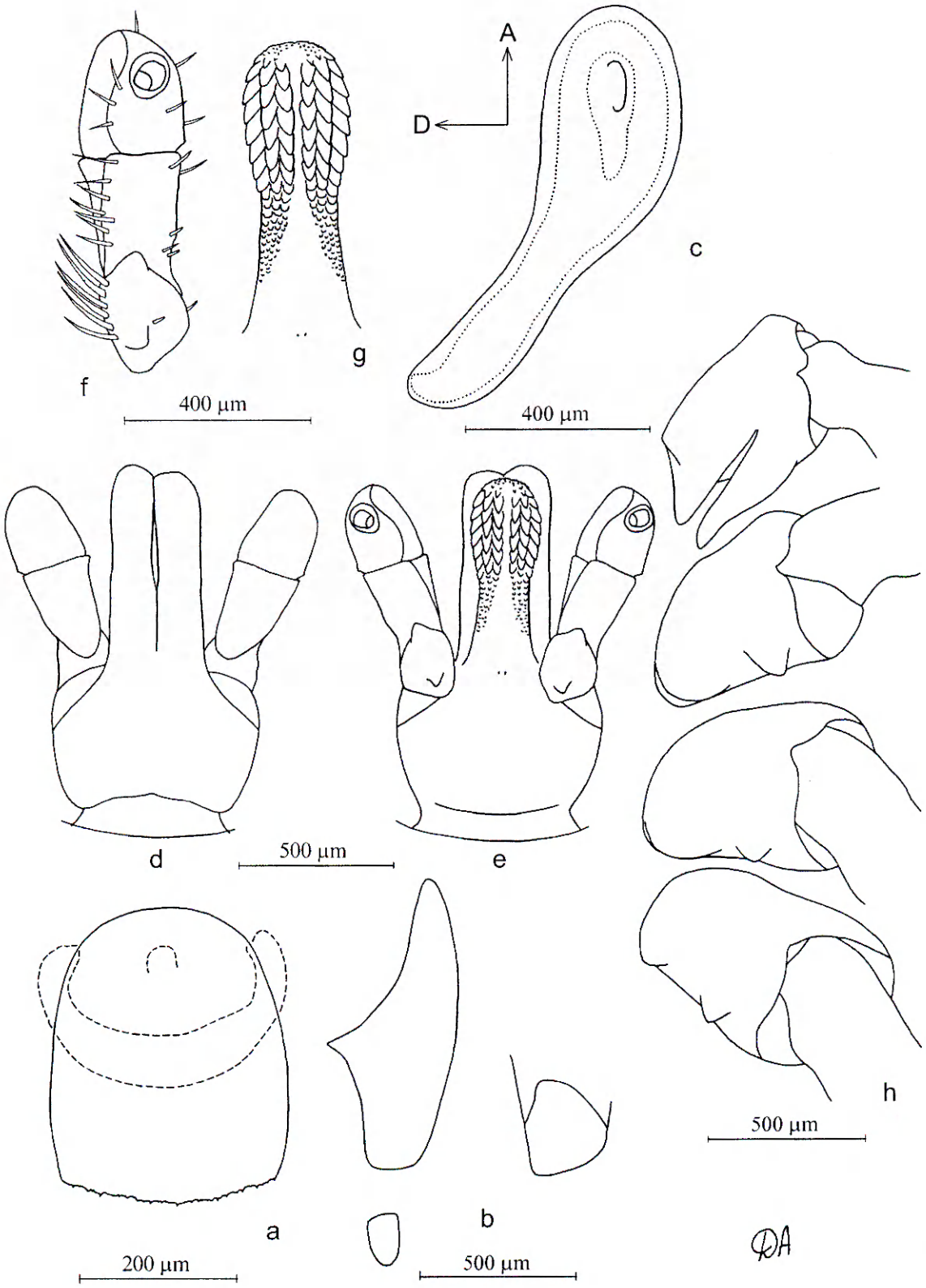


Fig. 2. *Hyalomma anatolicum*, male: a — genital structures; b — anal plates; c — spiracular plate (A — anterior; D — dorsal); d — gnathosoma dorsally; e — gnathosoma ventrally; f — palp ventrally; g — hypostome; h — coxae.

ly; pale marbling absent; posterolateral angles poorly defined or practically absent; cervical and lateral grooves shallow and extend to posterior margin of scutum; large punctations sparse, denser laterally, in cervical fields, and anteriorly in central field; scutum uniformly covered with fine punctations.

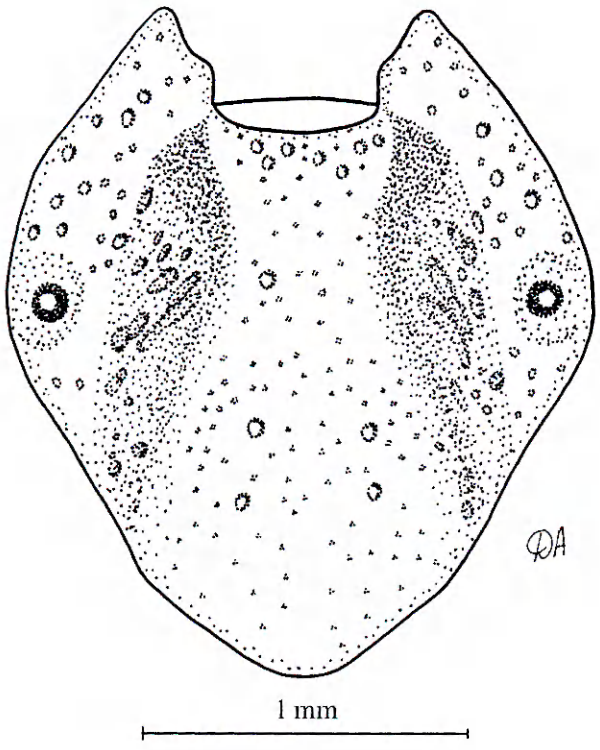


Fig. 3. *Hyalomma anatolicum*, female, scutum.

Genital structures (Fig. 4a): genital aperture wide, shallow, rounded; vestibular portion of vagina not bulging. *Spiracular plate* (Fig. 4b): perforated portion of dorsal prolongation curved and relatively narrow. Circumspiracular setae sparse.

Basis capituli (Fig. 4c, d): dorsally lateral projections short, absent ventrally; dorsal posterior margin straight; dorsal cornua inconspicuous. *Palpi* (Fig. 4e): segment I with more than five ventromedial setae. *Hypostome* (Fig. 4f): club-shaped; denticulate portion slightly longer than denticle-free portion.

Coxae (Fig. 4g): posteromedial and posterolateral spurs on coxa I long, close together, tapering to apices; coxae II–IV each with distinct, broadly triangular, with rounded apex, posterolateral spur; coxae II and III each with poorly developed, broadly arcuate, posteromedial spur; internal spur on coxa IV distinct, broadly triangular. Colouration of the legs similar to male.

Nymph (Fig. 5a–f)

Scutum (Fig. 5a): length 487–698 (614±2.19, n=268), width 525–744 (627±2.05, n=277), ratio length: width 0.83–1.10 (0.98±0.003, n=268), length from posterior margin of eyes to posterior margin of scutum 162–275 (228±1.13, n=270), ratio width of scutum: length of posterior portion 2.38–3.53 (2.76±0.01, n=270); posterior margin of scutum varies from narrowly to broadly rounded; posterolateral margins moderately indented. *Setae of alloscutum* (Fig. 5b): cone-shaped, without dentation. *Spiracular plate* (Fig. 5c): oval; dorsal prolongation distinct, broad, blunt at apex; sub-marginal row of perforations incomplete.

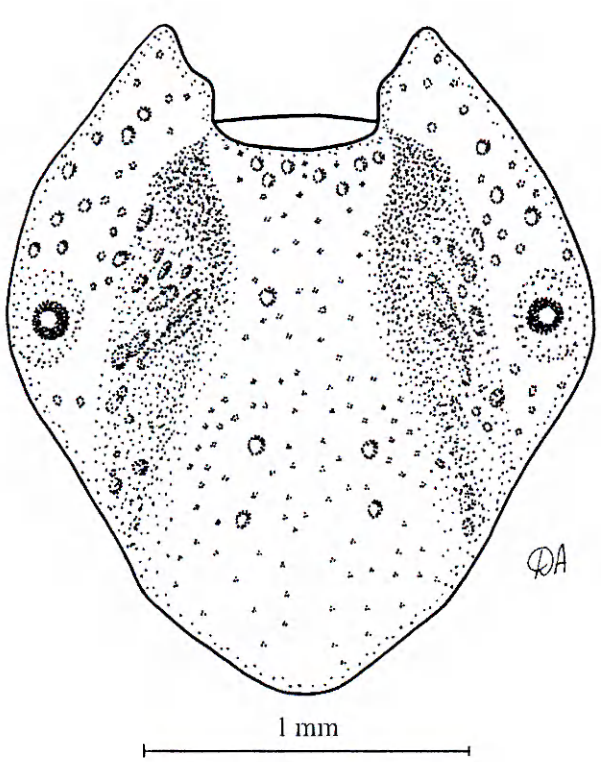
Basis capituli (Fig. 5d, e): length 351–502 (433±1.95, n=227), width 296–388 (338±0.95, n=270), ratio length: width 1.09–1.46 (1.28±0.004, n=224); anterolateral margin of basis capituli approximately half its width. *Palpi* (segment II) (Fig. 5d, e): length 167–228 (197±0.77, n=276), width 51–73 (62±0.07, n=275), ratio length: width 2.69–3.89 (3.21±0.01, n=275); palpal segment II proximally narrow, gradually expanding distally. *Hypostome* (Fig. 5e): length 182–277 (238±1.12, n=229), width 56–84 (68±0.35, n=241), ratio length: width 2.73–4.29 (3.49±0.02, n=228); transition of denticulate portion to denticle-free portion abrupt; denticulate portion nearly twice as long as denticle-free portion.

Coxae (Fig. 5f): spurs of coxa I long, narrow, triangular, nearly equal in length; coxae II-IV each with a single, moderate spur, spurs conspicuously decreasing in size from coxae II to IV; coxal pore absent.

Larva (Fig. 6a–d)

Scutum (Fig. 6a): length 251–308 (284±0.65, n=265), width 365–467 (412±1.14, n=292), ratio length: width 0.64–0.73 (0.69±0.001, n=265), length from posterior margin of eyes to posterior margin of scutum 68–97 (86±0.30, n=265), ratio width of scutum: length of posterior portion 4.12–6.17 (4.84±0.02, n=265). Posterior portion of scutum equal to 1/3 of scutum length, posterior margin of scutum broadly rounded with slight posterolateral depressions on either side of the apex.

Basis capituli (Fig. 6b, c): width 143–185 (165±0.39, n=292), subhexagonal dorsally, ventrally subrectangular; apex of dorsolateral projections directed slightly anteriorly; lateral projections appear acute from ventral view. *Palpi* (segments II and III) (Fig. 6b, c): length 106–132 (123±0.28, n=293), width 36–48 (41±0.11, n=290), ratio length: width 2.60–3.29 (2.97±0.01, n=290). *Hypostome* (Fig. 6c): length 92–123 (110±0.31, n=252), width 24–34 (30±0.09, n=281), ratio length: width 3.09–4.39 (3.67±0.01, n=252); median file with five large denticles; transition of denticulate portion to denticle-free portion abrupt; denticulate portion constitutes approximately ½ of hypostome length.



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Basis capituli (Fig. 5d, e): length 351–502 (433±1.95, n=227), width 296–388 (338±0.95, n=270), ratio length: width 1.09–1.46 (1.28±0.004, n=224); anterolateral margin of basis capituli approximately half its width. *Palpi* (segment II) (Fig. 5d, e): length 167–228 (197±0.77, n=276), width 51–73 (62±0.07, n=275), ratio length: width 2.69–3.89 (3.21±0.01, n=275); palpal segment II proximally narrow, gradually expanding distally. *Hypostome* (Fig. 5e): length 182–277 (238±1.12, n=229), width 56–84 (68±0.35, n=241), ratio length: width 2.73–4.29 (3.49±0.02, n=228); transition of denticulate portion to denticle-free portion abrupt; denticulate portion nearly twice as long as denticle-free portion.

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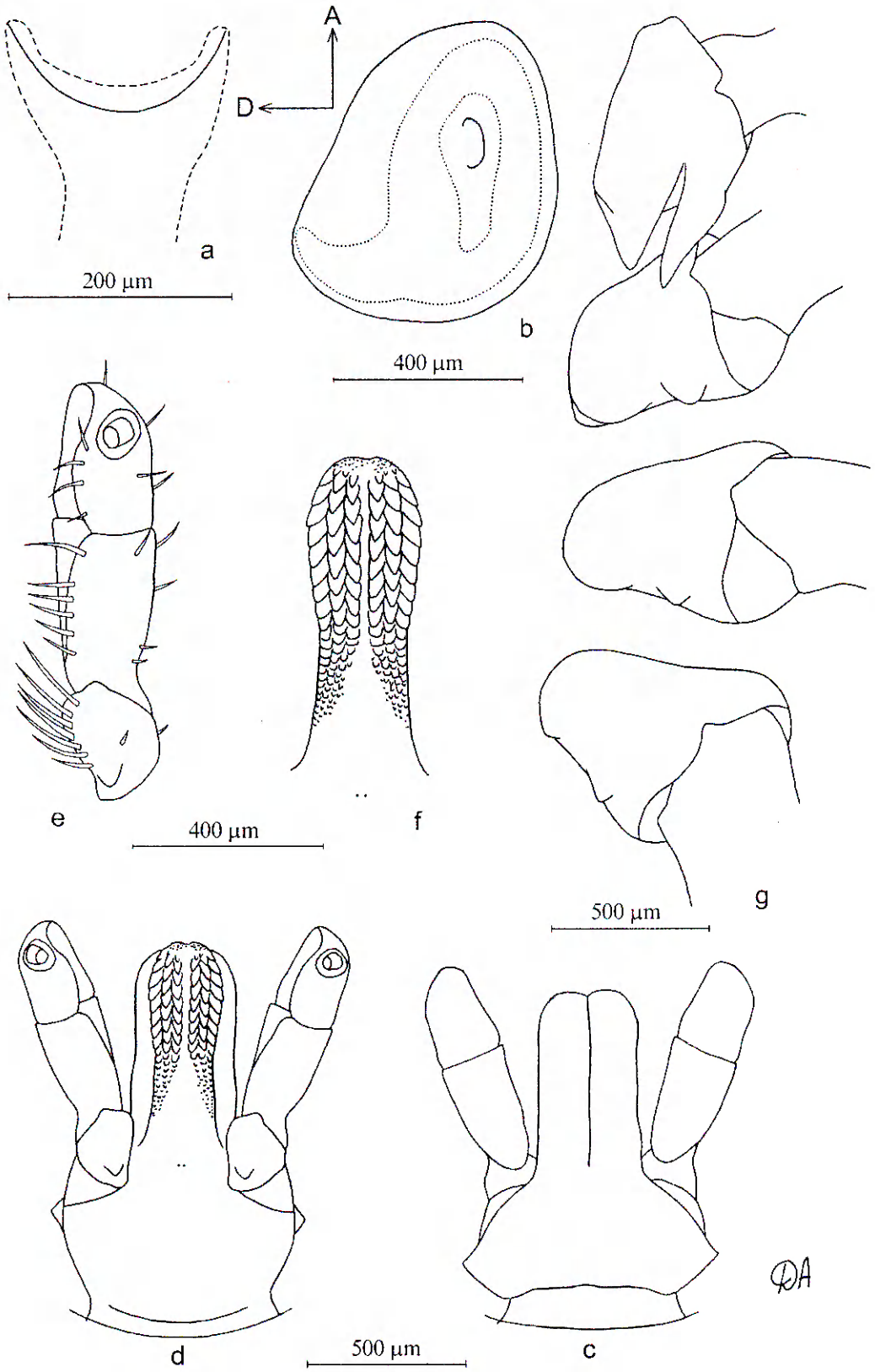

Fig. 4. *Hyalomma anatolicum*, female: a — genital structures; b — spiracular plate (A — anterior; D — dorsal); c — gnathosoma dorsally; d — gnathosoma ventrally; e — palp ventrally; f — hypostome; g — coxae.

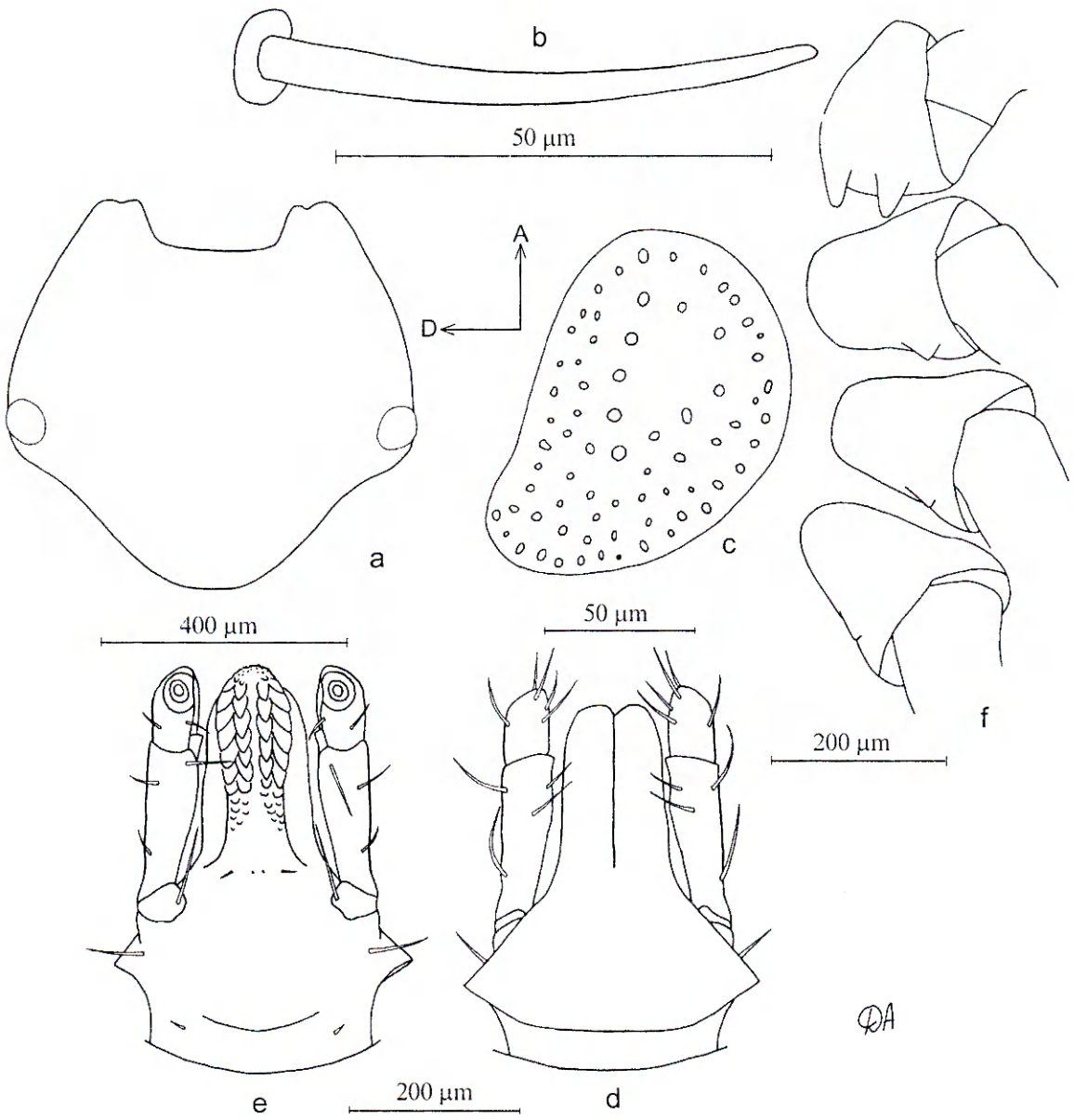

Fig. 5. *Hyalomma anatolicum*, nymph: a — scutum; b — seta of alloscutum; c — spiracular plate (A — anterior; D — dorsal); d — gnathosoma dorsally; e — gnathosoma ventrally; f — coxae.

Coxae (Fig. 6d): coxa I with single large, subtriangular, with tapering apex spur; coxae II–III each with single, moderate, distinct spur; spur of coxa II arcuate; spur of coxa III triangular or arcuate. *Genu I*: length 140–196 (173±0.52, n=287), width 43–59 (52±0.21, n=156), ratio length: width 2.76–3.72 (3.31±0.01, n=156).

Hyalomma (*Euhyalomma*) *excavatum* Koch, 1844

The holotype (male, Aegypten; Ehrenberg leg.; Holotypus, ZMB 1078) was redescribed by Feldman-Muhsam [1954]. Deposition of the type specimen is unknown [Hoogstraal and Kaiser, 1959; Moritz and Fischer, 1981].

Material examined: more than 600 males, 400 females, 200 nymphs, and 650 larvae collected in Albania, Greece, Cyprus, Morocco, Algeria, Libya, Egypt, Sudan, Djibouti, Turkey, Jordan, Lebanon, Somalia, Syria, Iraq, Iran, Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, and Afghanistan. Both field-collected and laboratory-reared specimens were studied.

Male (Fig. 7, 8a–h)

Conscutum (Fig. 7): length 3.60–5.30 (4.54±0.05, n=65), width 2.20–3.30 (2.71±0.04,

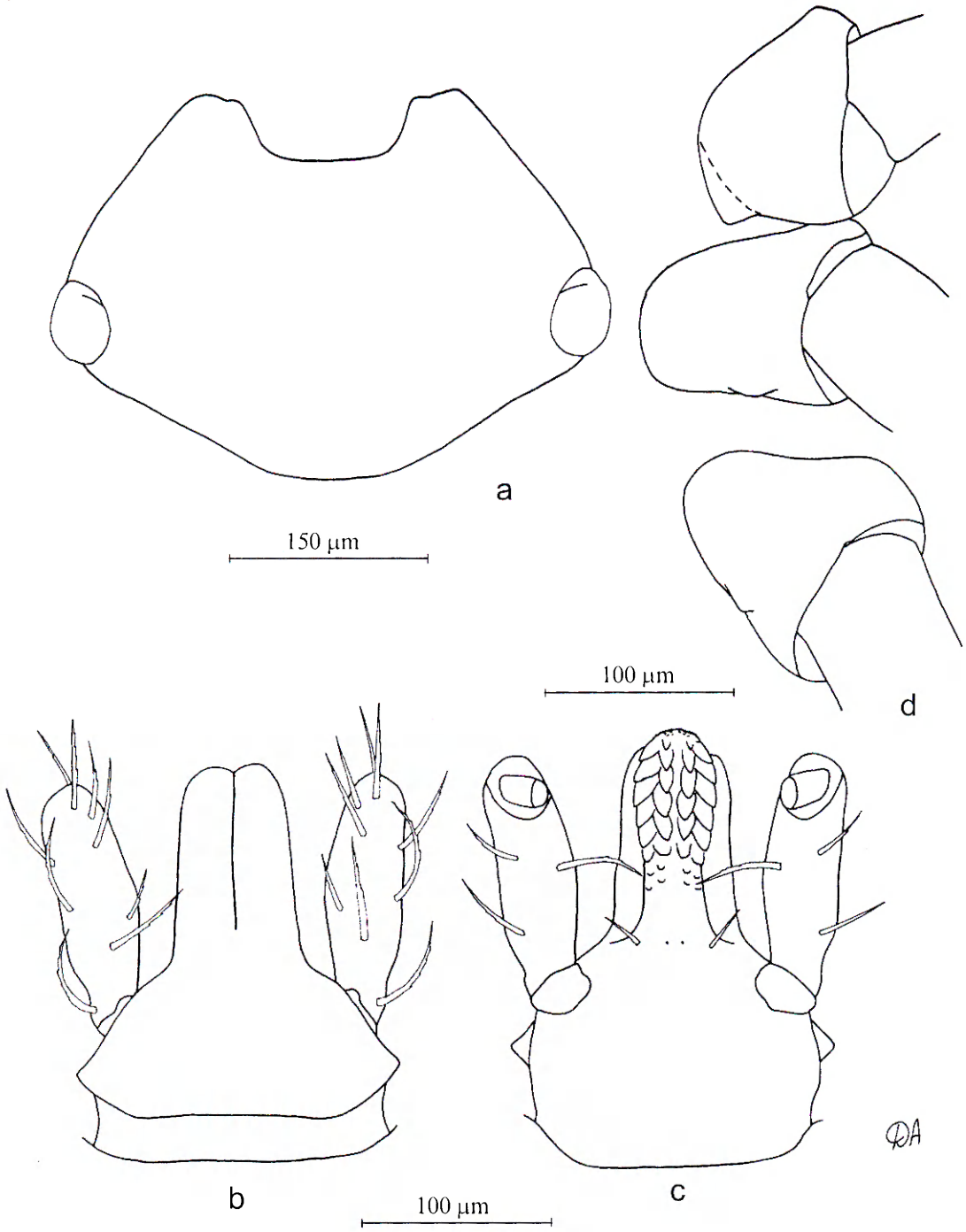

Fig. 6. *Hyalomma anatolicum*, larva: a — scutum; b — gnathosoma dorsally; c — gnathosoma ventrally; d — coxae.

n=52), ratio length: width 1.48–2.00 (1.67±0.01, n=52); dark in colour – from red-brown to very dark-brown; pale marbling often present anteriorly; broadly oval in shape; widest in posterior half; cervical, lateral and marginal grooves as in *H. anatolicum*; posteromedial groove not reaching the parma, from which it is separated by a distinct ridge variably connected to the paramedian festoons; paramedial grooves relatively deep; caudal field demarcated laterally by prominent ridges; punctations on caudal field usually small and dense, sometimes contiguous, large punctations sparse; small punctations evenly dispersed on remainder of conscutum, large punctations sparse, denser on lateral fields; parma usually well defined; two distinct pairs of festoons on posterior margin of conscutum.

Genital structures (Fig. 8a) as illustrated. *Anal plates* (Fig. 8b): adanal plates as in *H. anatoli-*

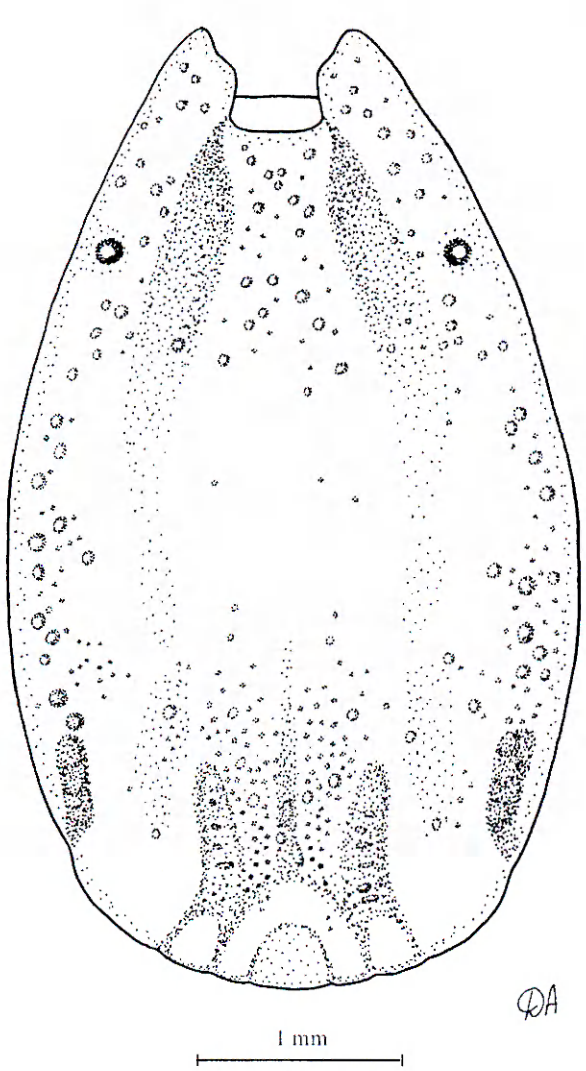

Fig. 7. *Hyalomma excavatum*, male, conscutum.

cum; subanal plates larger than in *H. anatolicum* and sub-circular. *Spiracular plate* (Fig. 8c) as in *H. anatolicum*.

Basis capituli (Fig. 8d, e): without lateral projections; dorsal posterior margin usually visibly concave; dorsal cornua modest. *Palpi* (Fig. 8f): segment I with more than five ventromedial setae. *Hypostome* (Fig. 8g) as in *H. anatolicum*.

Coxae (Fig. 8h): spurs of coxae I–IV as in *H. anatolicum*. Ivory coloured enamelling diffuse on dorsal aspects of leg segments; ivory coloured bands unclear.

Female (Fig. 9, 10a–g)

Scutum (Fig. 9): length 1.65–2.87 (2.29±0.02, n=145), width 1.52–2.75 (2.11±0.02, n=145), ratio length: width 0.90–1.30 (1.09±0.005, n=145); dark in colour – from red-brown to black-brown, darker laterally; ivory coloured marbling in anterior part of scutum usually distinct; posterolateral angles of scutal margin prominent; cervical and lateral grooves deeper than in *H. anatolicum*, extending to posterior margin of scutum; large punctations sparse, denser on lateral, cervical and anterior third of central field; small punctations evenly scattered on scutum.

Genital structures (Fig. 10a) and *spiracular plates* (Fig. 10b) as in *H. anatolicum*.

Basis capituli (Fig. 10c, d): dorsally lateral projections short, absent ventrally; posterodorsal margin straight; dorsal cornua inconspicuous. *Palpi* (Fig. 10e): segment I with more than five ventromedial setae. *Hypostome* (Fig. 10f) as in *H. anatolicum*.

Coxae (Fig. 10g): spurs of coxae I–IV as in *H. anatolicum*. Colouration of the legs similar to male.

Nymph (Fig. 11a–f)

Scutum (Fig. 11a): length 442–600 (534±3.09, n=138), width 500–700 (599±3.44, n=139), ratio length: width 0.76–1.09 (0.89±0.005, n=137), length from posterior margin of eyes to posterior margin of scutum 151–233 (195±1.44, n=139), ratio width of scutum: length of posterior portion 2.44–3.92 (3.08±0.02, n=139); posterior margin broadly rounded; posterolateral margins moderately indented. *Setae of alloscutum* (Fig. 11b): setiform without denticles. *Spiracular plate* (Fig. 11c): oval; dorsal prolongation poorly developed; marginal perforations close to margin of entire spiracular plate, submarginal row incomplete.

Basis capituli (Fig. 11d, e): length 319–427 (373±1.98, n=117), width 274–368 (322±1.51, n=137), ratio length: width 1.04–1.27 (1.16±0.005, n=117); anterolateral margin less than ½ width of basis capituli. *Palpi* (segment II) (Fig. 11d, e): length 131–202 (171±1.03, n=139), width 51–69 (61±0.35, n=139), ratio length: width 2.09–3.67 (2.81±0.02, n=139); palpal segment II proximally narrow, gradually expanding distally. *Hypostome* (Fig. 11e): length 168–235 (200±1.30, n=113), width 56–78 (69±0.48, n=125), ratio length: width 2.48–3.76 (2.92±0.03, n=113); transition of denticulate portion to denticle-free portion sharp; denticulate portion more than twice as long as denticle-free portion.

Coxae (Fig. 11f): spurs of coxae I–IV as in *H. anatolicum*; coxal pore absent.

Larva (Fig. 12a–d)

Scutum (Fig. 12a): length 237–291 (260±0.65, n=313), width 342–445 (391±1.04, n=318), ratio length: width 0.61–0.73 (0.66±0.001, n=312), length from posterior margin of eyes to posterior margin of scutum 63–97 (76±0.34, n=319), ratio width of

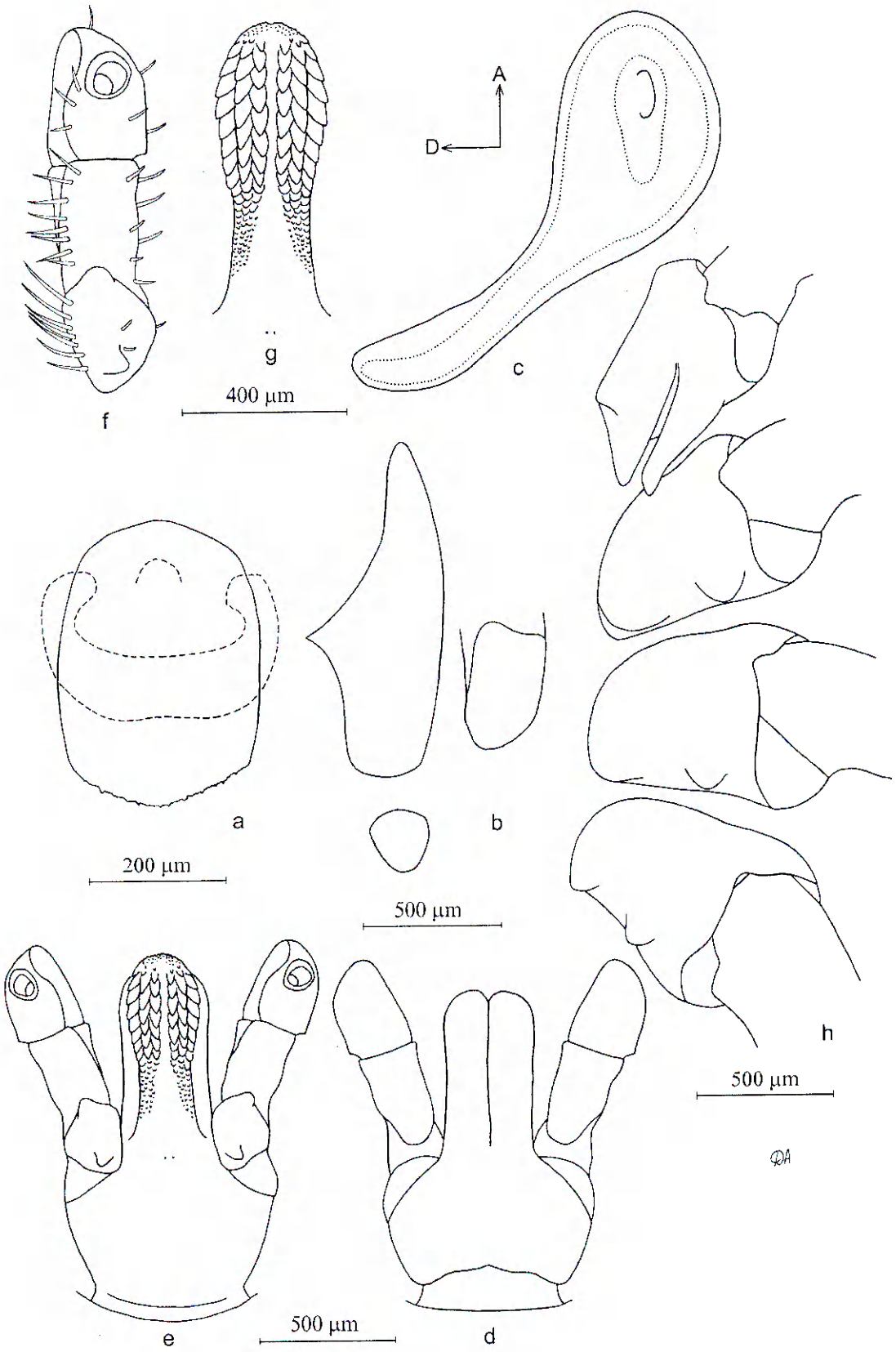

Fig. 8. *Hyalomma excavatum*, male: a — genital structures; b — anal plates; c — spiracular plate (A — anterior; D — dorsal); d — gnathosoma dorsally; e — gnathosoma ventrally; f — palp ventrally; g — hypostome; h — coxae.

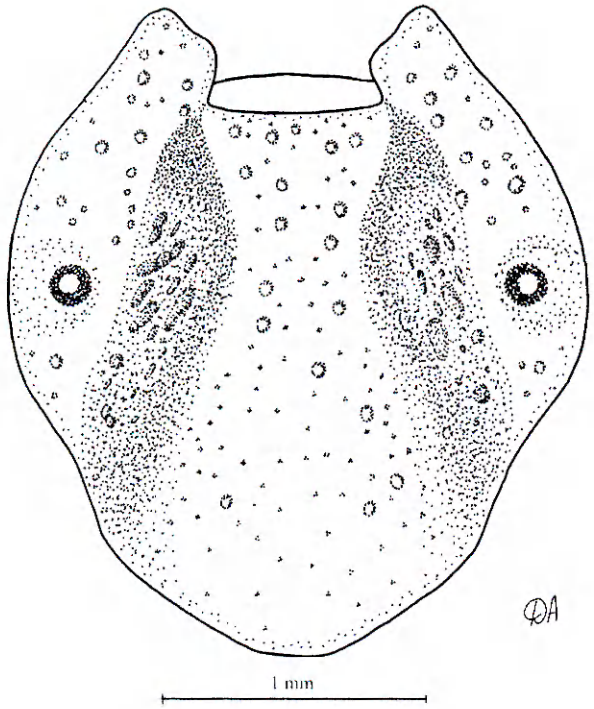

Fig. 9. *Hyalomma excavatum*, female, scutum.

scutum: length of posterior portion 4.19–6.23 (5.15±0.02, n=318); posterior portion of scutum equal to 1/3 of scutum length, posterior margin of scutum broadly rounded with slight posterolateral depressions on either side of the apex.

Basis capituli (Fig. 12b, c): width 133–174 (151±0.36, n=312); shape as in *H. anatolicum*. *Palpi* (segments II and III) (Fig. 12b, c): length 98–120 (109±0.25, n=313), width 36–52 (41±0.12, n=313), ratio length: width 2.00–3.00 (2.70±0.01, n=313). *Hypostome* (Fig. 12c): length 87–112 (97±0.27, n=280), width 25–34 (29±0.09, n=300), ratio length: width 2.83–3.89 (3.34±0.01, n=280); median file with five large denticles; transition of denticulate portion to denticle-free portion sharp; denticulate portion constitutes approximately ½ of hypostome length.

Coxae (Fig. 12d): spurs of coxae I–III as in *H. anatolicum*. *Genu I*: length 134–168 (151±0.35, n=317), width 42–59 (49±0.18, n=187), ratio length: width 2.33–3.60 (3.06±0.01, n=187).

DIFFERENTIAL DIAGNOSIS

Hyalomma anatolicum	*Hyalomma excavatum*
Male (Figs 1, 2a–h, 7, 8a–h)	
1. Small ticks: length and breadth of conscutum usually less than 4 mm and 2.3 mm respectively.	1. Large ticks: length and breadth of conscutum usually greater than 4 mm and 2.3 mm respectively.
2. Conscutum narrowly oval.	2. Conscutum broadly oval.
3. Conscutum widest at midlength.	3. Conscutum widest posteriorly.
4. Scutum, gnathosoma and coxae light – yellowish- or reddish-brown.	4. Scutum, gnathosoma and coxae dark – red- or black-brown.
5. Ivory colored marbling absent on scutum.	5. Ivory colored marbling often present on scutum.
6. Punctations in caudal field larger and sparse.	6. Punctations in caudal field smaller and dense.
7. Lateral ridges bordering caudal field squat.	7. Lateral ridges bordering caudal field elevated.
8. Posteromedial groove separated from parma by contiguous punctations or smooth, slight elevation.	8. Posteromedial groove separated from parma by distinct ridge connected to paraparmal festoons.
9. Ivory colored enameling of leg segments indistinct.	9. Ivory colored enameling defuse on dorsal aspects of leg segments.
Female (Figs 3, 4a–g, 9, 10a–g)	
1. Small ticks: length and breadth of scutum usually lesser than 2 mm and 1.9 mm respectively.	1. Large ticks: length and breadth of scutum usually greater than 2 mm and 1.9 mm respectively.
2. Scutum, gnathosoma and coxae light – yellowish- or reddish-brown.	2. Scutum, gnathosoma and coxae dark – red- or black-brown.
3. Ivory colored marbling absent on scutum.	3. Ivory colored marbling usually present on scutum.
4. Posterolateral angles of scutum indistinct or absent.	4. Posterolateral angles of scutum distinct.
5. Cervical and lateral scutal grooves shallow.	5. Cervical and lateral scutal grooves deeper.
6. Ivory colored enameling of leg segments indistinct.	6. Ivory colored enameling defuse on dorsal aspects of leg segments.

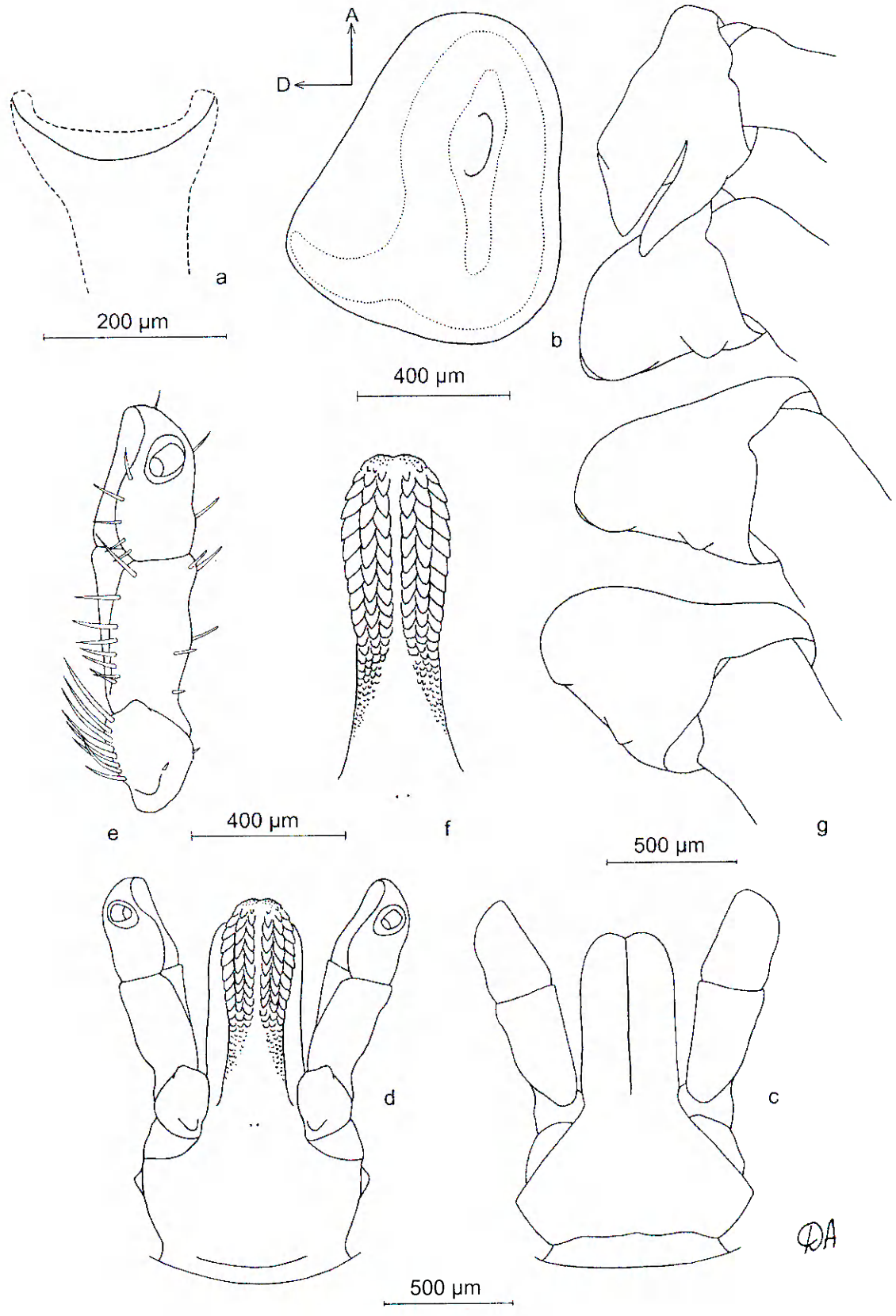

Fig. 10. *Hyalomma excavatum*, female: a — genital structures; b — spiracular plate (A — anterior; D — dorsal); c — gnathosoma dorsally; d — gnathosoma ventrally; e — palp ventrally; f — hypostome; g — coxae.

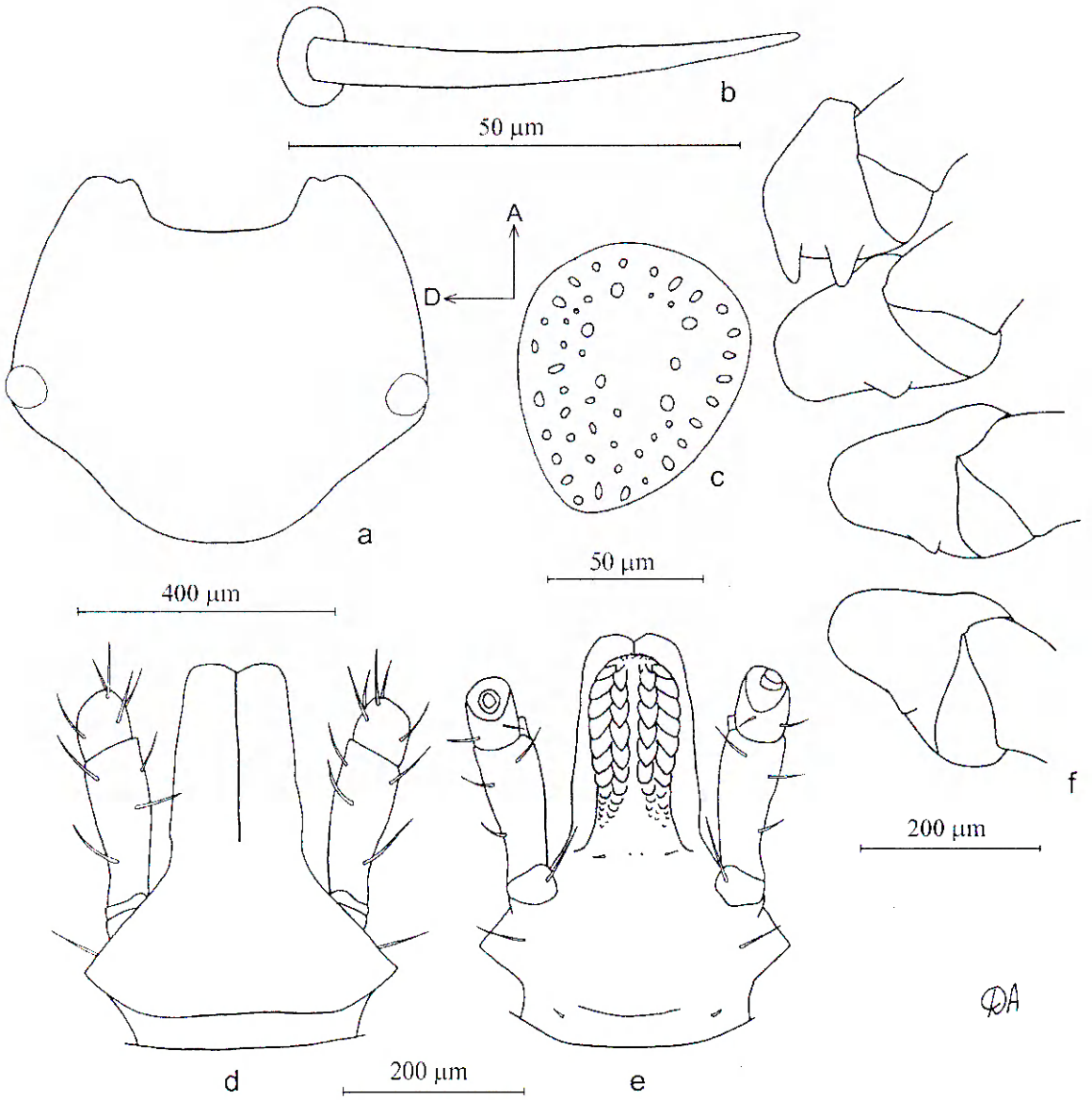

Fig. 11. *Hyalomma excavatum*, nymph: a — scutum; b — seta of alloscutum; c — spiracular plate (A — anterior; D — dorsal); d — gnathosoma dorsally; e — gnathosoma ventrally; f — coxae.

Nymph (Figs 5a–f, 11a–f)

1. Large. All measurements (excluding width of palpi and hypostome) statistically significantly different from those of *H. excavatum*.
2. Dorsal prolongation of spiracular plate well developed, marginal perforations separated from edge of spiracular plate at base of dorsal prolongation.
3. Anterolateral margin of basis capituli nearly ½ that of width of basis capituli; ventrally lateral projections in posterior half of length of basis capituli.
4. Hypostome longer and narrower than in *H. excavatum*.

1. Small. All measurements (excluding width of palpi and hypostome) statistically significantly different from those of *H. anatolicum*.
2. Dorsal prolongation of spiracular plate poorly developed, marginal perforations close to edge of spiracular plate.
3. Anterolateral margin of basis capituli shorter than ½ of width of basis capituli; ventrally lateral projections in middle or in anterior half of length of basis capituli.
4. Hypostome shorter and broader than in *H. anatolicum*.

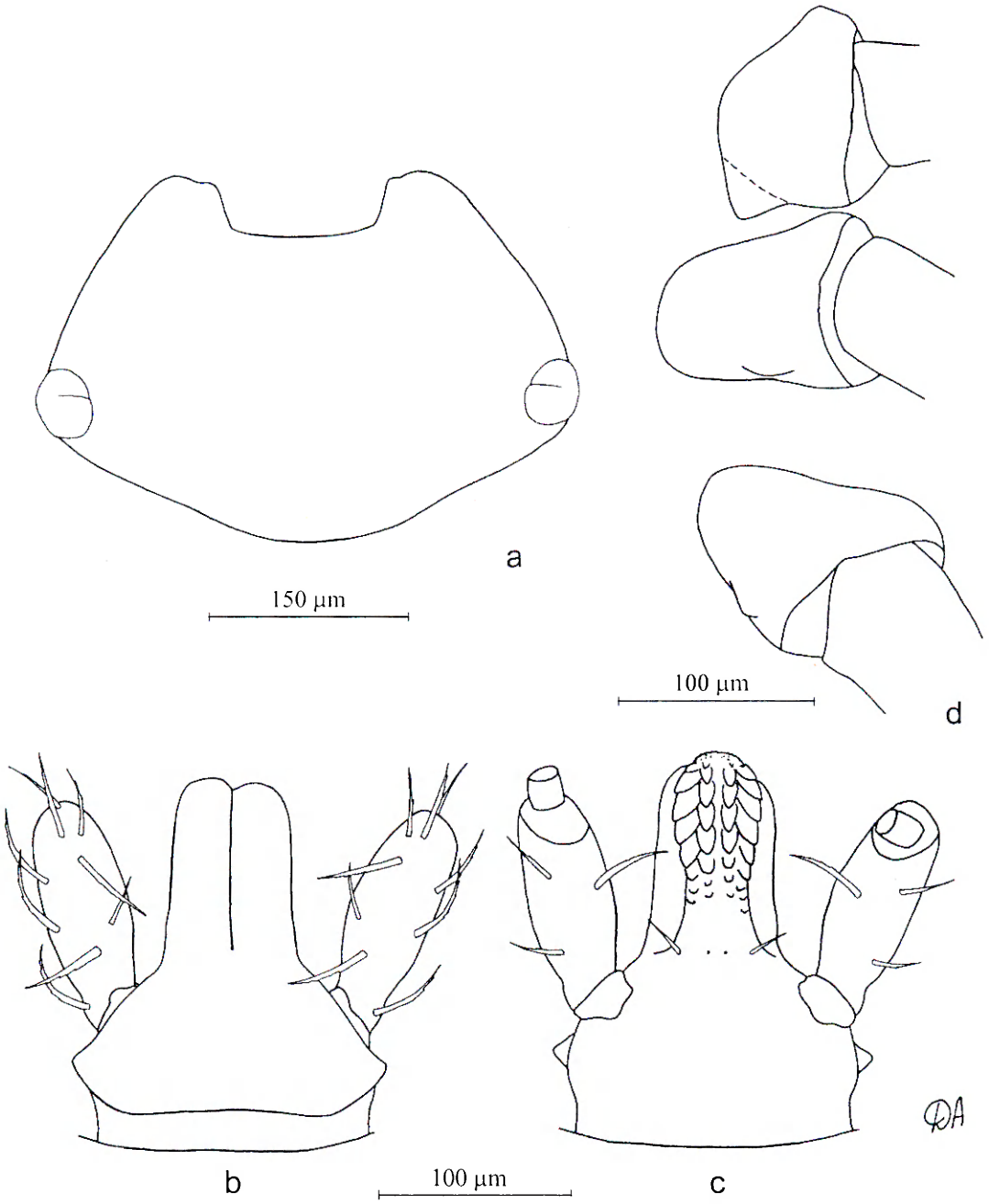

Fig. 12. *Hyalomma excavatum*, larva: a — scutum; b — gnathosoma dorsally; c — gnathosoma ventrally; d — coxae.

Larva (Figs 6a–d, 12a–d)

1. Large. All measurements (excluding width of palpi and hypostome) statistically significantly different from those of *H. excavatum*.

1. Small. All measurements (excluding width of palpi and hypostome) statistically significantly different from those of *H. anatolicum*.

CONCLUSION

External morphological characters were used as the main criteria for the differentiation of *H. anatolicum* from *H. excavatum* and for determination of their taxonomic status. A peculiarity of these species is that quantitative characters of the immature stages, especially the larvae, serve as chief features for distinguishing *H. anatolicum* from *H. excavatum*.

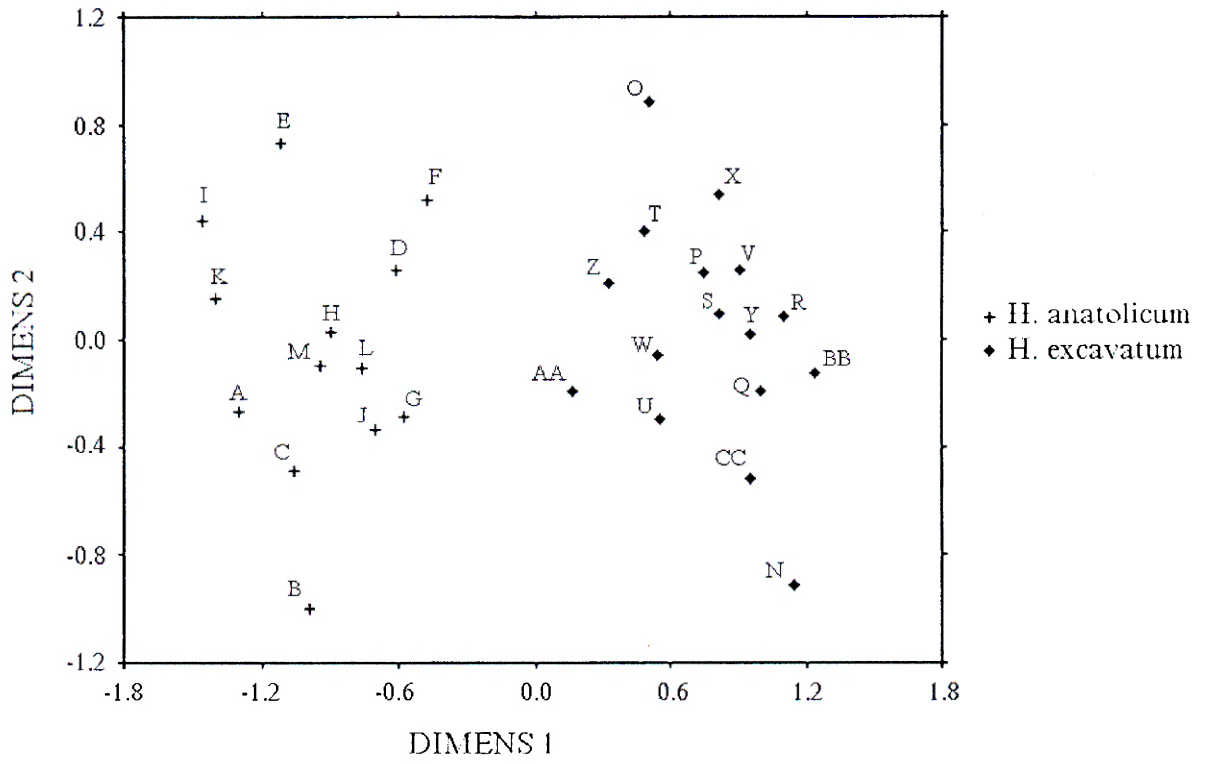

Fig. 13. Results of multidimensional scaling for larvae *H. anatolicum* and *H. excavatum*.
H. anatolicum. *A* — Egypt, Giza; *B* — Armenia; *C* — Iran, Marand; *D* — Kazakhstan, Tyul'kubas; Turkmenistan: *E* — Kaakhka, *F* — 2nd Tedjenstroi, *G* — Sakar-Chaga, *H* — Chaganly, *I* — Ashgabat, *J* — Uzbekistan, Gazalkent; Tajikistan: *K* — no locality, *L* — Chavalai, *M* — Dushanbe.
H. excavatum. Egypt: *N* — Giza, *O* — El Hammam; Turkmenistan: *P* — Karasu, *Q* — Delili, *R* — Mamedkul', *S* — Erikli, *T* — Kisyl-Atrek, *U* — Kara-Kala, *V* — El Dere, *W* — Domra, *X* — Tuver, *Y* — Karakhan, *Z* — Karlyuk; *AA* — Uzbekistan, Termez; Tajikistan: *BB* — Tigrovaya balka, *CC* — Nigniy Pyandzh.

The larval stage does not exhibit qualitative morphological characters, but because larvae are morphologically the most stable life stage, their quantitative morphological characters are paramount towards the differentiation of species, and this is clearly illustrated by multidimensional scaling (Fig. 13). The nymph possesses several qualitative morphological characters, but quantitative characters also provide a means of discrimination between the species, and this is clearly illustrated in the results obtained from multidimensional scaling (Fig. 14). However, because of variations in the size of nymphs, which in turn depend on the degree of engorgement of the preceding larvae, the level of variability increases in comparison to the larvae. The same pattern of relationship between quantitative and qualitative characters was present in the adults, but the number of characters exceeds those in the immature stages. Variability in quantitative characters also increased because of variations in the size of the adults, and this largely depended on the degree of engorgement of the antecedent stages. New characters were identified and existing ones more precisely defined for the specific differentiation of adults.

An additional important specific criterion is size inversion during ontogenesis. The larva and nymph of *H. anatolicum* are large, but the male and female are small. The converse is true for *H. excavatum*, the larva and nymph are small and the adults are large. This phenomenon has been recorded in other closely related species in other ixodid tick genera [Filippova, 1999].

A biological, but important aid towards making a decision on the specific rank of these taxa is the host-parasite specificity of the immature stages. With few exceptions the larvae and nymphs of *H. anatolicum* parasitize medium-sized and large mammals (ungulates), and a number of collections contained both nymphs and adults recovered from a single host (cattle). On the other hand the immature stages of *H. excavatum* parasitize small mammals, with hares being the largest of these.

The occurrence of regions in which *H. anatolicum* and *H. excavatum* are present sympatrically is a further indirect criterion for specific independ-

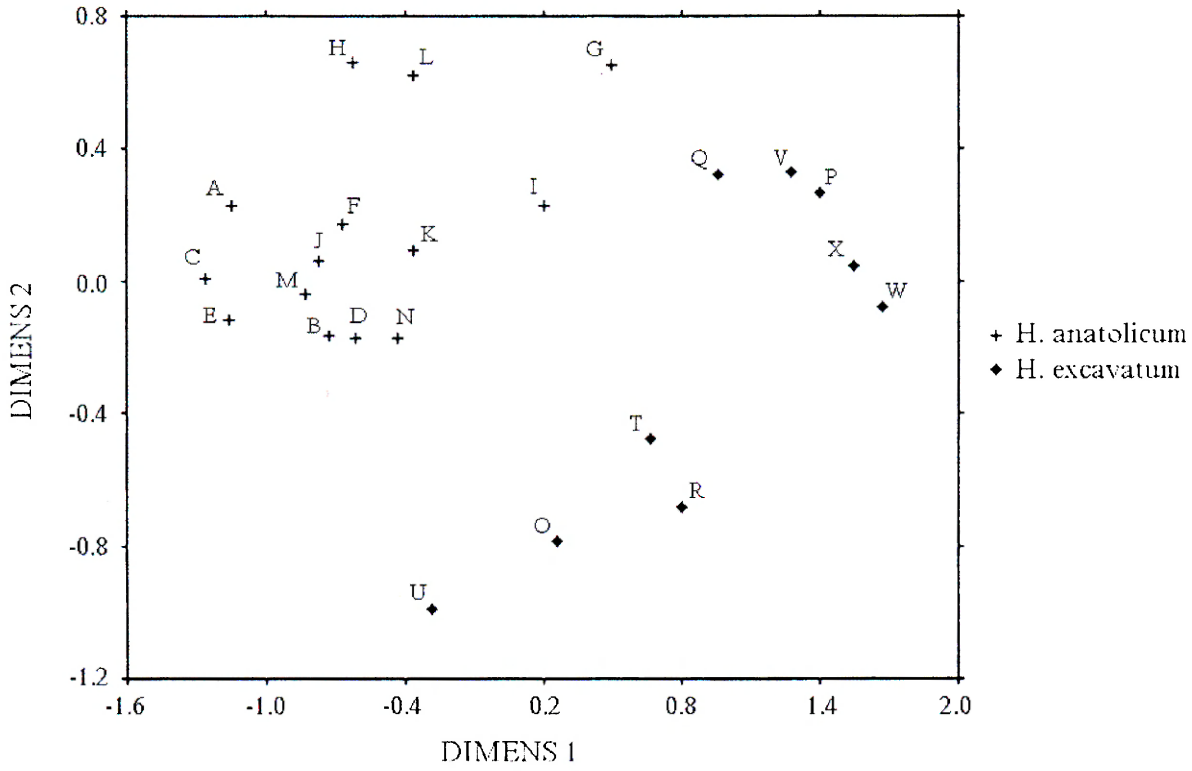

Fig. 14. Results of multidimensional scaling for nymphs *H. anatolicum* and *H. excavatum*.
H. anatolicum. *A* — Egypt, Aswan; Armenia: *B* — Arazdayan, *C* — Davalu; Azerbaijan: *D* — Kubatlinskiy dist., *E* — Djul'fa; Turkmenistan: *F* — Nizhnee Chuli, *G* — Chaganly, *H* — Kaakhka, *I* — Sakar-Chaga; Uzbekistan: *J* — no locality, *K* — Gazalkent; Tajikistan: *L* — Chavalai, *M* — Dushanbe, *N* — Kulyab.
H. excavatum. *O* — Egypt, Giza; Turkmenistan: *P* — Kara-Kala, *Q* — Karasu, *R* — Erikli, *S* — Mamedkul', *T* — Manysh, *U* — Karlyuk; Tajikistan: *V* — Kurgan-Tyube, *W* — Tigrovaya balka, *X* — Nizhniy Pyandzh.

ence. The origins of the collections examined revealed that sympatry occurred in parts of Sudan, Egypt, Southern Uzbekistan and Tajikistan. The distribution of *H. excavatum* to a large extent coincides with that of the more widely distributed *H. anatolicum* and it can hence be assumed that sympatry is more common than that recorded. Parasitism of cattle by the adults of both species further emphasizes their sympatry. Literature references to the distribution of these ticks can, however, be misleading because of the previously-discussed confusion in their nomenclature.

Finally comparative morphological analysis of all stages of development of both species and the existence of some eco-geographical peculiarities confirm the validity of the separate specific identities of *H.* (*E.*) *anatolicum* and *H.* (*E.*) *excavatum*.

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