

First contribution to the mayflies of Jordan

(Insecta: Ephemeroptera)

Jean-Luc Gattolliat, Laurent Vuataz, Michel Sartori

Abstract. Up to now, the mayfly fauna of Jordan has been completely unknown. Based on material recently collected at approximately 30 localities, a first contribution is provided. At least seven species of Ephemeroptera belonging to three different families occur in Jordan. With four species, the Baetidae is by far the most common and diversified family. Two new species, *Nigrobaetis vuatazi* Gattolliat & Sartori n.sp. and *Baetis monnerati* Gattolliat & Sartori n.sp., are described in both larval and imaginal stages. The association of the ontogenetic stages was based on mitochondrial DNA (COI gene). *Nigrobaetis vuatazi* is closely related to *Nigrobaetis arabiensis* Gattolliat & Sartori, 2008, recently described from United Arab Emirates, but differs notably from European species especially *Nigrobaetis niger* (Linnaeus, 1761) and *Nigrobaetis digitatus* (Bengtsson, 1912). *Baetis monnerati* belongs to the *bucerus* species-group, which is known to be very common in the Levant but less frequent in Central Europe. The two other baetid species, *Cloeon dipterum* (Linnaeus, 1761) and *Procloeon pennulatum* (Eaton, 1870), are widely distributed in the Western Palaearctic and have already been reported from the Levant. Caenidae are represented by *Caenis antoniae* Malzacher, 1992 and *Caenis parabrevipes* Malzacher, 1992, and Leptophlebiidae by *Choroterpes (Euthraulius) ortalii* Sartori, 1992. These three species were originally described from Israel and have not been reported since then. These reports increase their geographic range to the east and are of significant importance for conservation purposes as their former distribution was extremely restricted.

Key words. Systematics, faunistics, Levant, new species, Baetidae, Caenidae, Leptophlebiidae.

Introduction

Mayflies (Ephemeroptera) are merolimnic insects: the larval stage is dominant and is strictly aquatic, while the imaginal stage is extremely brief and on the wing. Mayflies are able to colonise every kind of freshwater habitat but are mainly diversified in lotic habitats (streams and rivers). They are distributed worldwide with the highest diversity in tropical areas. The order encompasses over 3000 species, over 400 genera and 42 families (BARBER-JAMES et al. 2008). The fauna of desert and arid areas is obviously poorly diversified, as suitable habitats are very limited.

Jordan is part of the Levant. The climate is considered Mediterranean with dry summers and rainfall mainly occurring from November to March. The western part of the country is mountainous and includes the Great Rift Valley of the Jordan River with negative altitudes. The majority of the country consists of arid plateaux with sporadic oases and seasonal water streams. A great part of the country receives less than 400 mm of rain a year and may be classified as a semi-arid region (TARAWNEH & KADIOGLU 2002). Most of the suitable areas for mayflies are therefore located in the western part.

Jordan remains the only country of the Levant from which no report of mayflies is available. KOCH (1980, 1981, 1988) provided the first global overview of mayflies from the Levant. He reported 36 species of mayflies belonging to eight families (Baetidae, Caenidae,

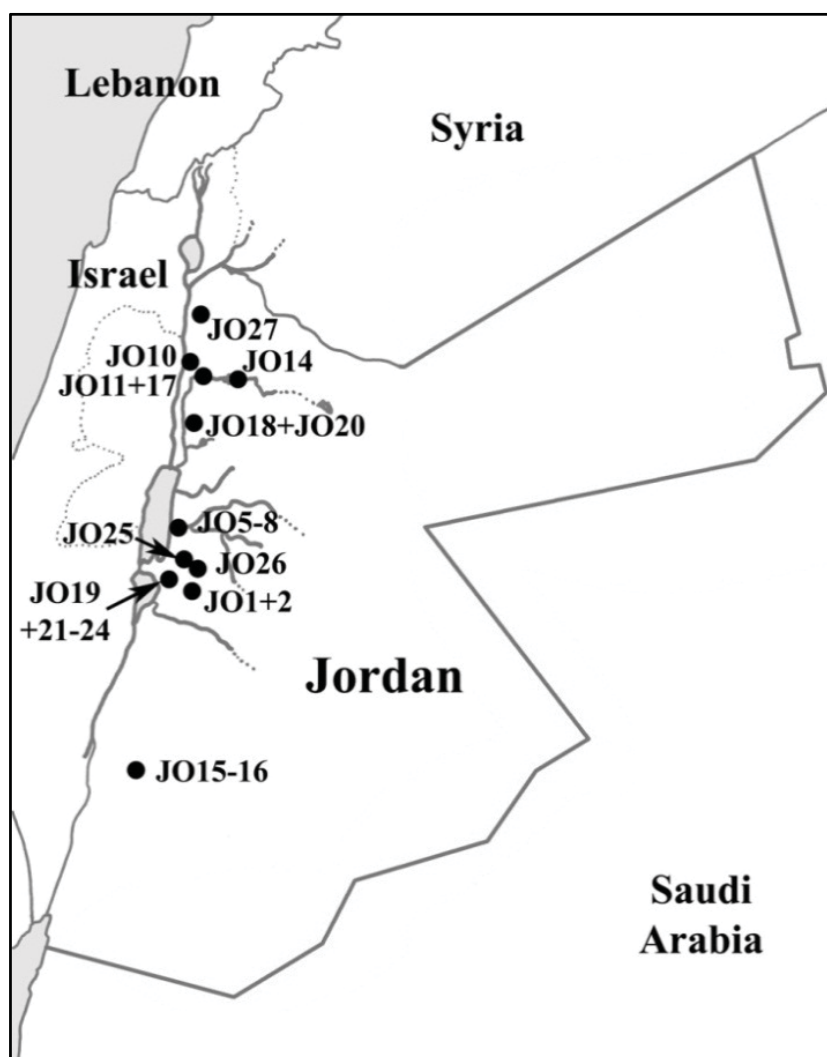


Fig. 1. Map of the sampling localities.

Ephemerellidae, Heptageniidae, Leptophlebiidae, Oligoneuriidae, Potamanthidae and Prosopistomatidae). The fauna of Lebanon was studied in detail and new species, likely to be endemic from this area, were described (THOMAS & DIA 1984, 1985, MARIE et al. 2000, 2001). The first survey of the fauna of Israel was made by SAMOCHA, who mentioned several morphospecies but in most cases without formal specific identification (SAMOCHA 1972). Shortly after this, the Heptageniidae were studied in detail with the description of six new species belonging to five different genera (DEMOULIN 1973). Subsequently, Caenidae, Ephemerellidae, Leptophlebiidae and Palingeniidae were subject to complete taxonomic and faunistic studies, with the description of four new species that are so far only known from Israel (MALZACHER 1992, SARTORI 1992). The fauna of Israel presently encompasses 15 species, but the study of the Baetidae, which is probably the most common and diversified family of mayflies, is still in progress. The fauna of the Arabian Peninsula has been the subject of important studies and currently includes eight species belonging to three families: Baetidae, Caenidae and Leptophlebiidae. While some areas such as the United Arab Emirates or parts of Saudi Arabia are relatively well known (THOMAS & SARTORI 1989, SARTORI & GILLIES 1990, GATTOLLIAT & SARTORI 2008), other areas such as Yemen remain virtually unknown.

Material and methods

All the studied material was collected by Christian MONNERAT (CSCF, Neuchâtel, Switzerland) during four sampling campaigns in April 2009, August 2009, November 2009 and December 2010. Larvae were collected using a sieve with a 1.5 mm mesh while imagos were caught with a handnet. Twenty-eight localities were sampled, and mayflies were found in 25 of them (Fig. 1).

The association of larval and adult stages is often challenging in mayflies, although it is a key step in the description process of new species. As no rearing was performed in the field and the association of the ontogenetic stages based on morphological characters is difficult, we used sequence divergence of the mitochondrial cytochrome c oxidase subunit I (COI) gene (the animal “barcode”) for association of both stages. Eight specimens (five larvae and three imagos) belonging to the different baetid “morphospecies” were selected for genetic analysis. A 658 bp fragment of the COI gene was sequenced using LCO1490 and HCO2198 primers (FOLMER et al. 1994). All laboratory procedures, edition and alignment of sequences were conducted as described in VUA-TAZ et al (2011). A Maximum Likelihood tree was reconstructed using PhyML 3.0 (GUINDON & GASCUEL 2003) under the best evolutionary model (GTR + Γ) selected following the second-order Akaike information criterion (AICc) implemented in MrAIC 1.4.4 (NYLANDER 2004). We used 3% sequence divergence (Kimura 2-parameter) as the maximal value for intraspecific divergence (HEBERT et al. 2003). This threshold value closely matches the maximum intraspecific (3.4%) and minimum interspecific (3.3%) sequence divergence previously observed in mayflies (BALL et al. 2005; WEBB et al. 2007).

All material examined, including the holotypes of the new species, is housed in the Museum of Zoology, Lausanne, Switzerland.

Systematics

Baetidae

Nigrobaetis vuatazi Gattolliat & Sartori n.sp.

Specimens examined: *Holotype*: JO5-8: 1 male larva. Jordan; Wadi Mujib, close to Dead Sea; 31°27'N, 35°34'E, -381 m b.s.l.; 7.iv.2009, coll. C. MONNERAT. – *Paratypes*: 18 ♂ larvae, 31 ♀ larvae (1 sequenced larva: GL7: EMBL accessions: HE651543). Same data as holotype. – JO20: 1 ♂ larva, 1 ♀ larva (1 sequenced larva: GL9: EMBL accessions: HE651544). Jordan; Wadi Hasa; 31°59'N, 35°39'E, 235 m a.s.l.; 12.xi.2009. JO24: 9 ♂ imagos (1 sequenced imago: GL3: EMBL accessions: HE651542). Jordan; Wadi Ibn Hammad; 31°18'N, 35°18'E, 100 m a.s.l.; 17.xii.2010. All coll. C. MONNERAT. – *Other material*: JO21: 1 ♀ subimago. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 75 m a.s.l.; 15.xii.2010. All coll. C. MONNERAT.

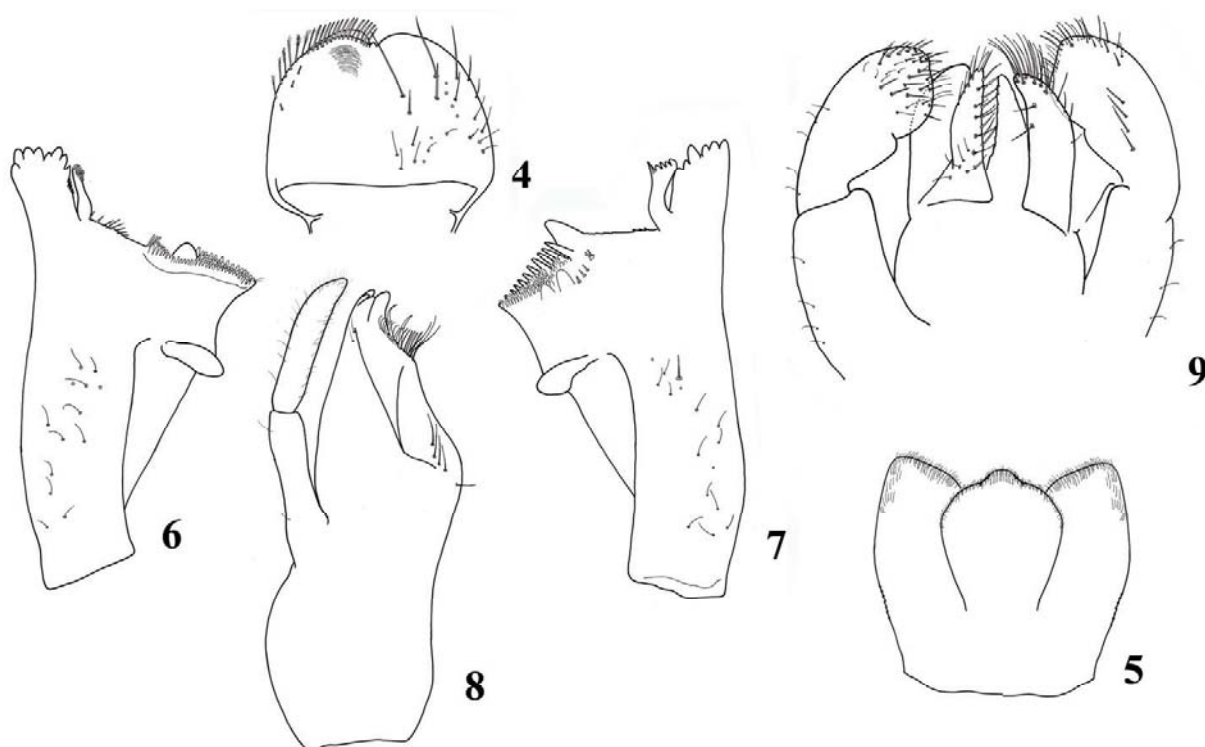
Diagnosis. Larva: general colouration brown except tergites I, IV, VIII and IX ecru (Fig. 18). Antennae close to each other with a small carina (Fig. 19). Mouthparts characteristic of *Nigrobaetis*. Legs (Fig. 10) stocky, femora dorsally with stout apically rounded setae, distal half of ventral margin with stout, broad and pointed setae, dorsal margin of midtibiae with spatulate setae (Fig. 12). Hindwing pads present. Seven pairs of gills, gill I reduced (Fig. 14). Margin of the paraprocts with restricted number of denticles (Fig. 17). – Imago: Forewing hyaline with hyaline venation and double intercalary veins (Fig. 20). Hindwing with an erect costal spur, two longitudinal veins, none of them bifurcated, no additional veinlets (Fig. 22). Segments I and II of male gonopods without expansion or contraction, segment III very long (Fig. 24).



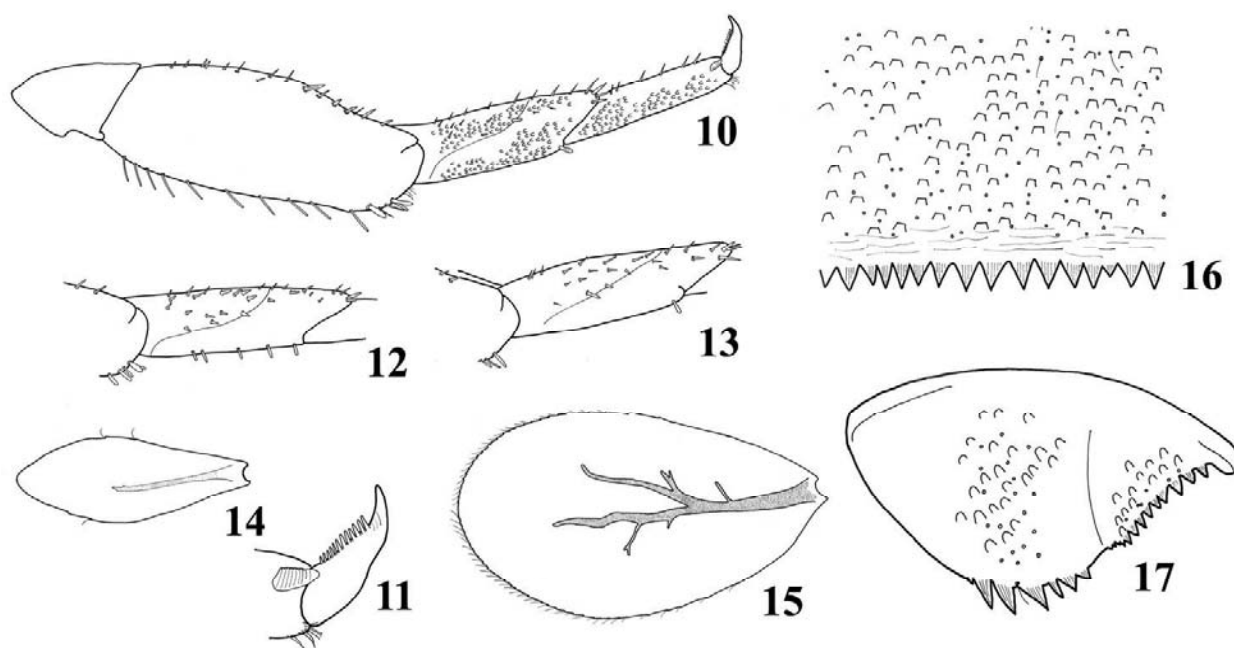
Figs 2-3. Important collecting localities: 2; Wadi Ibn Hammad (JOR25). 3: Wadi Weida'a (JOR19 + JOR22).

Description

Larva. Length (of full grown specimens). Female body 3.8-4.2 mm; cerci 1.8-2.0 mm; median caudal filament 1.2-1.4 mm; male body 3.7-4.0 mm; cerci 1.8-1.9 mm; median caudal filament 1.2-1.3 mm. – **Colouration**. General colouration brown (Fig. 18). Head uniformly brown without vermiform marks on vertex and frons. Turbinate eyes in male larvae purple brown. Legs whitish, except a brown stripe at distal 2/3 of femora. Thorax brown with a few ecru spots and marks but without clear pattern. Abdominal tergites II, III and V to VII medium brown, generally with two medioproximal ecru spots; tergites I and IX uniformly ecru to light brown; tergites IV and VIII ecru medially and brown laterally; tergite X ecru proximally and brown distally. Abdominal sternites light brown. Cerci ecru to light brown without bands or pattern. – **Head**. Antennae close to each other, with a small interantennal carina (Fig. 19). Dorsal surface of labrum (Fig. 4) with three long simple stout setae in the distal half and about 13 small fine setae scattered on the surface; ventral surface with three small pointed setae near lateral margin; distal margin fringed with two kinds of setae: 8 to 10 lateral ones long and divided into a brush and median ones shorter and slightly feathered. Hypopharynx (Fig. 5): lingua trilobed covered with minute stout setae; superlingua with thin setae apically and laterally. Right mandible (Fig. 6) with incisors composed of eight denticles, outer denticle smaller than others; prostheca with 8 denticles; tuft of setae between prostheca and mola restricted to a few stout setae; tuft of setae at apex of mola present. Left mandible (Fig. 7) with incisors composed of 6 denticles; prostheca with 4 broad denticles and a comb-shaped structure; margin crenelated between prostheca and mola but without setae; tuft of setae at apex of mola absent. Maxillae (Fig. 8) with 4 broad teeth; lacinia with 2 rows of setae, one row with abundant small setae ending with stouter and longer setae, second row with 2 long stout dentisetae; 2 thin setae at base of teeth, row of 4 long, stout setae at base of lacinia; one single seta perpendicular to margin of lacinia; palp two-segmented; segment I approximately 1.1 x length of segment II; segment II apically pointed, covered with thin setae. Labium (Fig. 9) with glossae equal in length to paraglossae; margins of glossae with medium setae, most apical setae very stout, ventral margin with a row of stout



Figs 4-9. Larval structures of *Nigrobaetis vuatazi* n.sp.: 4; labrum (left; ventral; right; dorsal). 5; hypopharynx. 6; right mandible. 7; left mandible. 8; right maxilla. 9; labium.

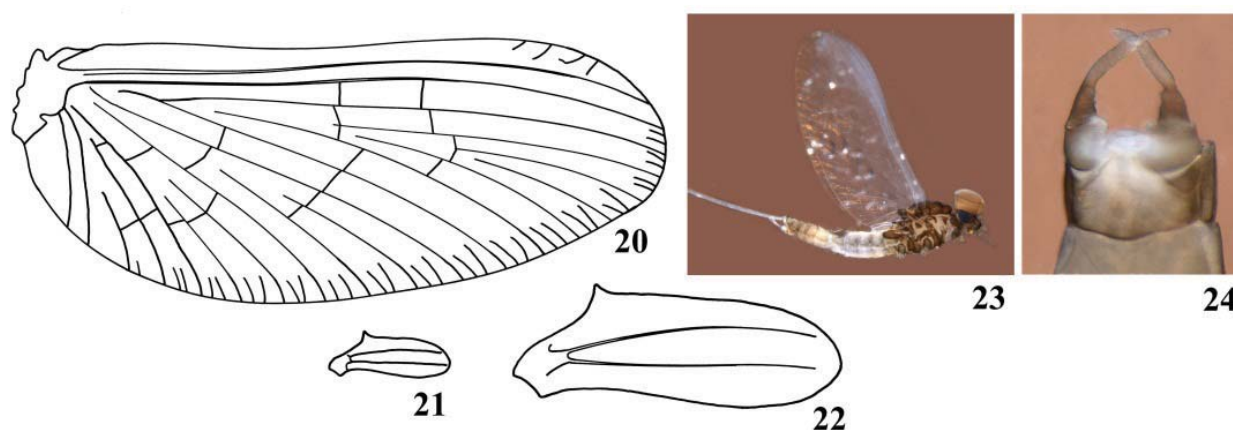


Figs 10-17. Larval structures of *Nigrobaetis vuatazi* n.sp.: 10; foreleg. 11; tarsal claw. 12; midtibia. 13; hind-tibia. 14; gill I. 15; gill IV. 16; distal margin of abdominal tergite IV. 17; paraproct.



Figs 18-19. Larval structures of *Nigrobaetis vuatazi* n.sp.: 18 (left); larvae *in toto* (left: female larva; right: male larva). 19 (right): ventral view of the head of a male larva.

setae and a few thin scattered setae; paraglossae falcate, with long, stout setae apically and laterally; labial palp three-segmented; segment I 0.9 x length of segments II and III combined; segment II with a dorsal oblique row of four long pointed setae; segment III truncated, with medium stout setae and a few small pointed setae. – **Thorax.** Forelegs (Fig. 10). Trochanter bare. Femora dorsally with one row of *ca.* ten long, stout apically rounded setae, without any other row of setae subparallel to dorsal margin; dorsoapical setal patch formed by 4 stout setae and a few thin setae; ventral margin with pointed short setae and a few pointed stouter and longer setae limited to the distal half; lateral margins almost bare. Tibiae bare, dorsally with a single spatulate seta apically; ventral margin with a few small pointed setae; tibiopatellar suture present; lateral margins covered by scale bases. Tarsi bare dorsally; ventral margin with 6 pointed setae; lateral margins covered by scale bases. Tarsal claws (Fig. 11) hooked with one row of about 12 acute teeth. Mid and hindlegs similar to forelegs except midtibiae with stout spatulate setae on the dorsal margin (Fig. 12), hindtibiae without spatulate setae (Fig. 13). Hindwing pads present. – **Abdomen.** Tergites with numerous scale bases, distal margin with broad triangular spines, distal part of tergites slightly shagreened (Fig. 16). Sternites with scale bases; posterior margin without spination. Gills on segments I to VII; gill I elongated and reduced (Fig. 14); gills II to VII elliptic and serrated all along margins, tracheation well visible but poorly divided (Fig. 15). Paraproct (Fig. 17) with abundant scale bases but almost no setae, margin with 6 broad, triangular spines; postero-lateral extension with scale bases, margin with 9 triangular medium spines and a few small ones laterally.



Figs 20-24. Imaginal structures of *Nigrobaetis vuatazi* n.sp.: 20; forewing. 21; hindwing (same magnification as forewing). 22; hindwing (high magnification). 23; male imago (lateral view). 24; male imago genitalia.

Male imago. Length. Body 3.2-3.4 mm; forewing 3.0-3.2 mm; hindwing 0.55-0.60 mm; foreleg: femur 0.68-0.73 mm, tibia 0.95-1.18 mm, tarsi T1 0.43-0.52 mm, T2 0.29-0.31 mm, T3 0.18-0.20 mm, T4 0.09-0.11 mm; cerci 5.2-6.2 mm. – **Colouration.** Head dark brown; scape and pedicel medium to dark brown, flagellum medium brown to ecru. Facetted surface of compound eyes orange brown, lateral face ecru apically with 6 to 8 rows of dark ommatidia (Fig. 23). Thorax dark brown. Legs: femora light brown, tibiae medium brown, tarsi light brown. Wings hyaline with hyaline venation. Abdomen: tergite I to VII ecru to light brown without mark or pattern; tergites VIII to X medium brown without mark or pattern. Sternite I light brown; sternites II to VII uniformly ecru without mark or pattern; sternites VIII and IX light brown. Cerci ecru. Genitalia ecru except segment I and external margin of basal segment medium brown. – **Forewing** (Fig. 20): pterostigma with about 4 cross-veins not reaching subcostal vein; double intercalary veins shorter than distance between corresponding main veins. – **Hindwing** (Figs. 21-22) with an erect costal spur at $\frac{1}{4}$ the length of wing; two longitudinal veins almost reaching margin, none of them bifurcated, without incomplete veinlets between main longitudinal veins. – **Genitalia** (Fig. 24): basal segment with inner margin not expanded apically; segments I and II almost completely fused; segment I progressively narrower, without expansion or contraction; segment II with parallel margins; segment III elongated, about 4x longer than broad.

Discussion

The number of gill pairs and the presence/absence of hindwing pads are usual features for separating the different species of *Nigrobaetis* in the larval stage. *N. vuatazi* possesses seven pairs of gills; and thus differs from the Palaearctic species *N. acinaciger* (Kluge, 1983), *N. digitatus* (Bengtsson, 1912), *N. niger* (Linnaeus, 1761) and *N. rhithralis* (Soldán & Thomas, 1983) and the Afrotropical species *N. harasab* (Soldán, 1977) which all have six pairs of gills. The three other Afrotropical species *N. colonus* Gattolliat, 2004, *N. cryptus* Gattolliat, 2004 and *N. bethunae* Lugo-Ortiz & de Moor, 2000 possess seven pairs of gills but do not have hindwing pads, contrary to *N. vuatazi*. *N. gracilis* (Bogoescu & Tabacaru, 1957), *N. numidicus* (Soldán & Thomas, 1983) and *N. arabiensis* Gattolliat & Sartori, 2008 are the only species with relatively close distribution which share the same features with *N. vuatazi*.

Moreover these three species also possess a paraproct with a restricted number of spines along the margin. The general shape of the legs (Fig. 10), especially the stocky tibiae, distinguishes *N. vuatazi* and *N. arabiensis* from *N. gracilis* and *N. numidicus*. *N. vuatazi*, *N. gracilis* and *N. numidicus* have spatulate setae on the dorsal margin of mid tibiae (Fig. 12) and sometimes also on hind tibiae; these spatulate setae are not present in *N. arabiensis*. *N. numidicus* can be distinguished from *N. vuatazi*, *N. gracilis* and *N. arabiensis* by the absence of setae between prostheca and mola of the right mandible (MÜLLER-LIEBENAU 1969, SOLDÁN & THOMAS 1983, GATTOLLIAT & SARTORI 2008).

The two species *N. vuatazi* and *N. arabiensis* are morphologically extremely similar. Besides the presence/absence of spatulate setae on mid tibiae (Fig. 12), other small characters allow them to be separated: the apex of the maxillary palp is pointed in *N. vuatazi* (Fig. 8) and rounded in *N. arabiensis*; tibiae and tarsi are covered with numerous scale bases in *N. vuatazi* (Fig. 10) while these are almost absent in *N. arabiensis*; the proximal denticles of the tarsal claws are much smaller in *N. arabiensis* than in *N. vuatazi*; the first pair of gills is more reduced and the tracheation of all gills is less developed and less visible in *N. arabiensis* than in *N. vuatazi* (Figs 14-15); the ventral margin of the femora of *N. arabiensis* is covered by abundant stout pointed medium setae while these are restricted to the distal half in *N. vuatazi* (Fig. 10); the tibiopatellar suture is indistinguishable in *N. arabiensis* while clearly visible on all legs of *N. vuatazi* (Fig. 10); the margin of the postero-lateral extension of the paraproct has more than 20 small denticles in *N. arabiensis* while there are less than ten in *N. vuatazi* (Fig. 17).

KOCH (1988) mentioned two species of *Nigrobaetis* from the Northern Levant: *N. digitatus* and *N. niger*. Both species were rare in the material from Syria and adjacent countries as only one specimen of each was collected. As mentioned above, *N. digitatus* and *N. niger* cannot be confused with *N. vuatazi* or *N. arabiensis* as these species differ according to the number of gills. KOCH (1988) considered that *N. digitatus* is also present in Israel based on SAMOCHA's report; we did not have the opportunity to check SAMOCHA's material but both the number of gills and the shape of the seventh pair of gills should allow a secure identification of the species.

The imago of *N. vuatazi* presents unusual characters within the genus. In most species of *Nigrobaetis*, the second vein of the hindwing is bifurcate. This is obviously not the case in *N. vuatazi* (Fig. 22). *N. numidicus* and *N. taiwanensis* (Müller-Liebenau, 1985) also possess the second vein not bifurcate (SOLDÁN & THOMAS 1983, MÜLLER-LIEBENAU 1985). *N. numidicus* possesses hindwings with three longitudinal veins (SOLDÁN & THOMAS 1983), while the hindwing of *N. vuatazi* has only two. In some species, such as *N. gracilis* and *N. numidicus*, the male gonopods are strongly narrowed between the apex of the first segment and the base of the second (MÜLLER-LIEBENAU 1969, SOLDÁN & THOMAS 1983), but this is not the case in *N. vuatazi*. The third segment of the gonopods is rather long, which is common in *Nigrobaetis* (Fig. 24), compared to other species of Baetini (MÜLLER-LIEBENAU 1969, SOLDÁN & THOMAS 1983).

The three sequenced specimens (two larvae GL7 and GL9 and one male imago GL3) proved to be undoubtedly conspecific as they share the same haplotype (0% divergence; Fig. 52).

Etymology

This species is dedicated to Laurent VUATAZ, specialist of molecular systematics and phylogeny of European and Malagasy Heptageniidae, for his constant help and friendship.

***Baetis monnerati* Gattolliat & Sartori n.sp.**

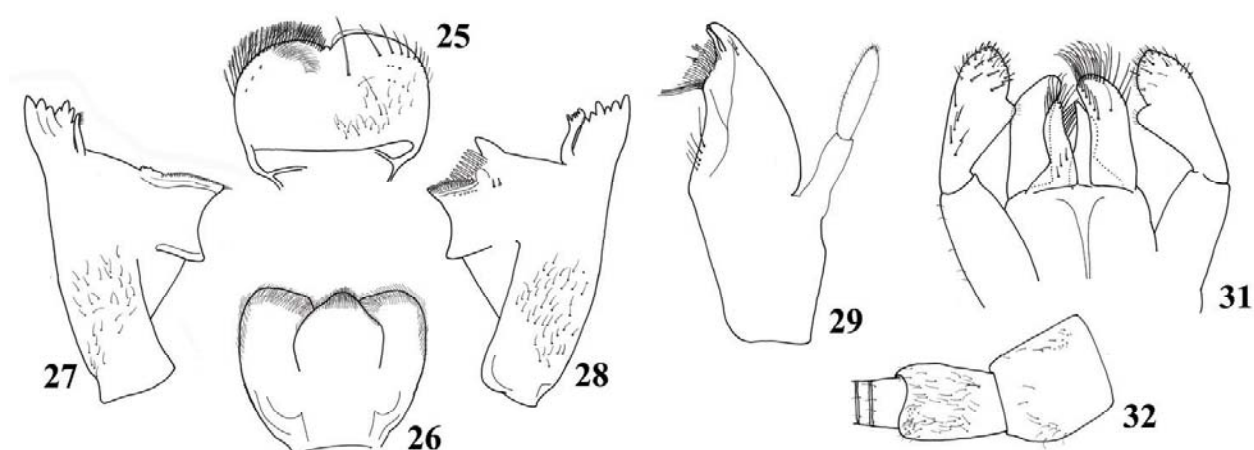
Specimens examined: *Holotype*: JO21: 1 ♀ larva. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 75 m a.s.l.; 15.xii.2010. Coll. C. MONNERAT. – *Paratypes*: JO21: 34 larvae. Same data as holotype. – JO1: 5 larvae. Jordan; Wadi Karak; 31°10'N, 35°41'E, 770 m a.s.l.; 7.iv.2009. – JO2: 3 larvae, 1 ♀ imago; Wadi Karak; 31°10'N, 35°41'E, 775 m a.s.l.; 7.iv.2009. – JO10: 14 larvae. Jordan; Wadi Kufrinja; 32°16'N, 35°37'E, 65 m a.s.l.; 6.viii.2009. – JO11: 1 larva. Jordan; Wadi Rajib; 32°13'N, 35°42'E, 325 m a.s.l.; 8.viii.2009. – JO14: 28 larvae. Jordan; Wadi Zarqa; 32°13', 35°52'E, 235 m a.s.l.; 11.viii.2009. – JO17: 4 larvae. Jordan; Wadi Rajib; 32°14'N, 35°41'E, 300 m a.s.l.; 7.xi.2009. – JO18: 22 larvae (1 sequenced larva GL6: EMBL accessions: HE651541); 10 ♂ imagos (1 sequenced imago GL1: EMBL accessions: HE651537). Jordan; Wadi Shu'yab; 31°58'N, 35°43'E, 310 m a.s.l.; 9.xi.2009. – JO19: 1 larva (1 sequenced larva GL4: EMBL accessions: HE651540). Jordan; Wadi Weida'a; 31°14'N, 35°35'E, 45 m a.s.l.; 11.xi.2009. – JO20: 3 larvae. Jordan; Wadi Hasa; 31°59'N, 35°39'E, 235 m a.s.l.; 12.xi.2009. – JO22: 7 ♂ imagos (1 sequenced imago GL5: EMBL accessions: HE651538). Jordan; Wadi Weida'a; 31°14'N, 35°35'E, 45 m a.s.l.; 9.xi.2009. – JO25 39 larvae (1 sequenced larva GL2: EMBL accessions: HE651539). Jordan; Wadi Ibn Hammad; 31°17'N, 35°41'E, 525 m a.s.l.; 17.xii.2010. – JO26: 8 larvae. Jordan; Wadi Ibn Hammad; 31°16'N, 35°41'E, 525 m a.s.l.; 17.xii.2010. All coll. C. MONNERAT. – *Other material*: JO2: 1 ♀ imago. Jordan; Wadi Karak; 31°10'N, 35°41'E, 775 m a.s.l.; 7.iv.2009. – JO15: 3 larvae. Jordan; Wadi Siyyagh upstream (near Wadi Musa); 30°19'N, 35°25'E, 855 m a.s.l.; 16.viii.2009. – JO16: 6 larvae. Jordan; Wadi Siyyagh downstream (near Wadi Musa); 30°19'N, 35°25'E, 860 m a.s.l.; 16.viii.2009. – JO27: 3 larvae. Jordan; Wadi Ziglab/Al Qulai'at; 32°31'N, 35°37'E, -115 m b.s.l.; 22.xii.2010. – JO23: 1 ♀ subimago. Jordan; Wadi Weida'a; 31°14'N, 35°35'E, 55 m a.s.l.; 15.xii.2010. All coll. C. MONNERAT.

Diagnosis

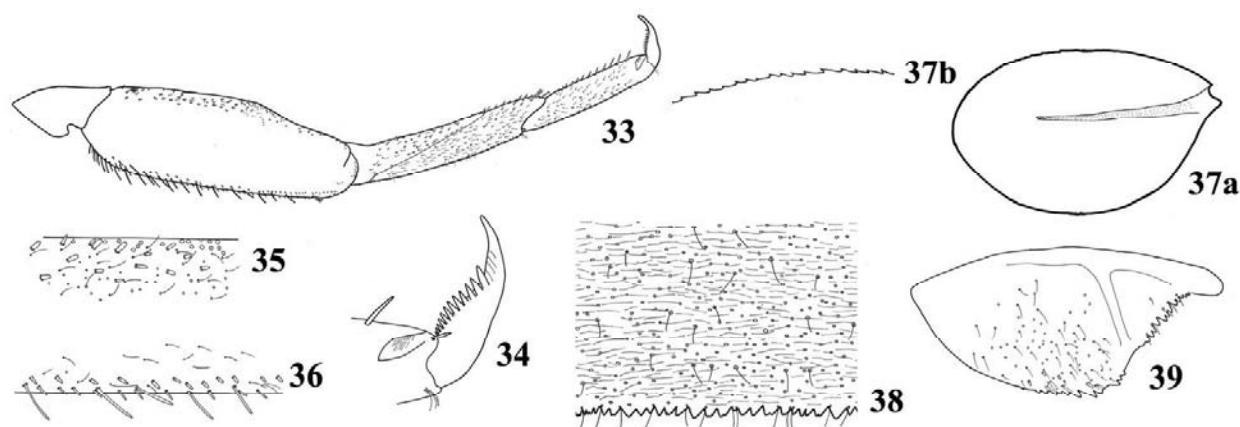
Larva: general colouration brown and ecru with contrasting pattern (Fig. 40). Mouthparts characteristic of *Baetis*, labial palp segment II moderately expanded apicolaterally, segment III conical and elongated (Fig. 31). Legs (Fig. 33): femora dorsally with one row of more than 20 apically rounded setae (Fig. 36), tarsal claw with one row of about 12 teeth without a pair of subapical setae (Fig. 34). Abdominal tergites without scale bases, distal margin generally with triangular spines, some blunt (Fig. 38). Paraprocts with a restricted number of denticles (Fig. 39). – **Imago:** Forewing hyaline with medium brown venation and double intercalary veins (Fig. 41). Hindwing with an erect costal spur, three longitudinal veins, none of them bifurcate, variable number of additional veinlets between second and third longitudinal veins (Figs. 42-44). Segments I and II of male gonopods without expansion or contraction, segment III ovoid (Fig. 45).

Description

Larva. Length (of full grown specimens). Female body 5.8-6.6 mm; cerci 3.2-3.4 mm; median caudal filament 2.3-2.6 mm; male body 5.2-6.0 mm; cerci 2.7-3.0 mm; median caudal filament 1.5-2.2 mm. – **Colouration.** Head uniformly brown with vermiform marks on vertex and frons. Turbinate eyes in male larvae honey brown. Legs whitish, except femora with ventral and dorsal margins brown and a brown stripe at 2/3. Thorax brown with ecru pattern. Abdominal tergites I to IV and VI to VIII medium brown with ecru pattern formed by a longitudinal band with a thin pattern laterally and a pair of distolateral dots; tergite V ecru except proximally and laterally medium brown; tergite IX ecru except a pair of brown triangular mark proximally; tergite X ecru except medium brown laterally (Fig. 40). Abdominal sternites uniformly ecru to light brown. Cerci ecru without bands or pattern.



Figs 25-32. Larval structures of *Baetis monnerati* n.sp.: 25; labrum (left; ventral; right; dorsal). 26; hypopharynx. 27; right mandible. 28; left mandible. 29; left maxilla. 31; labium. 32; detail of antenna (scape and pedicel).



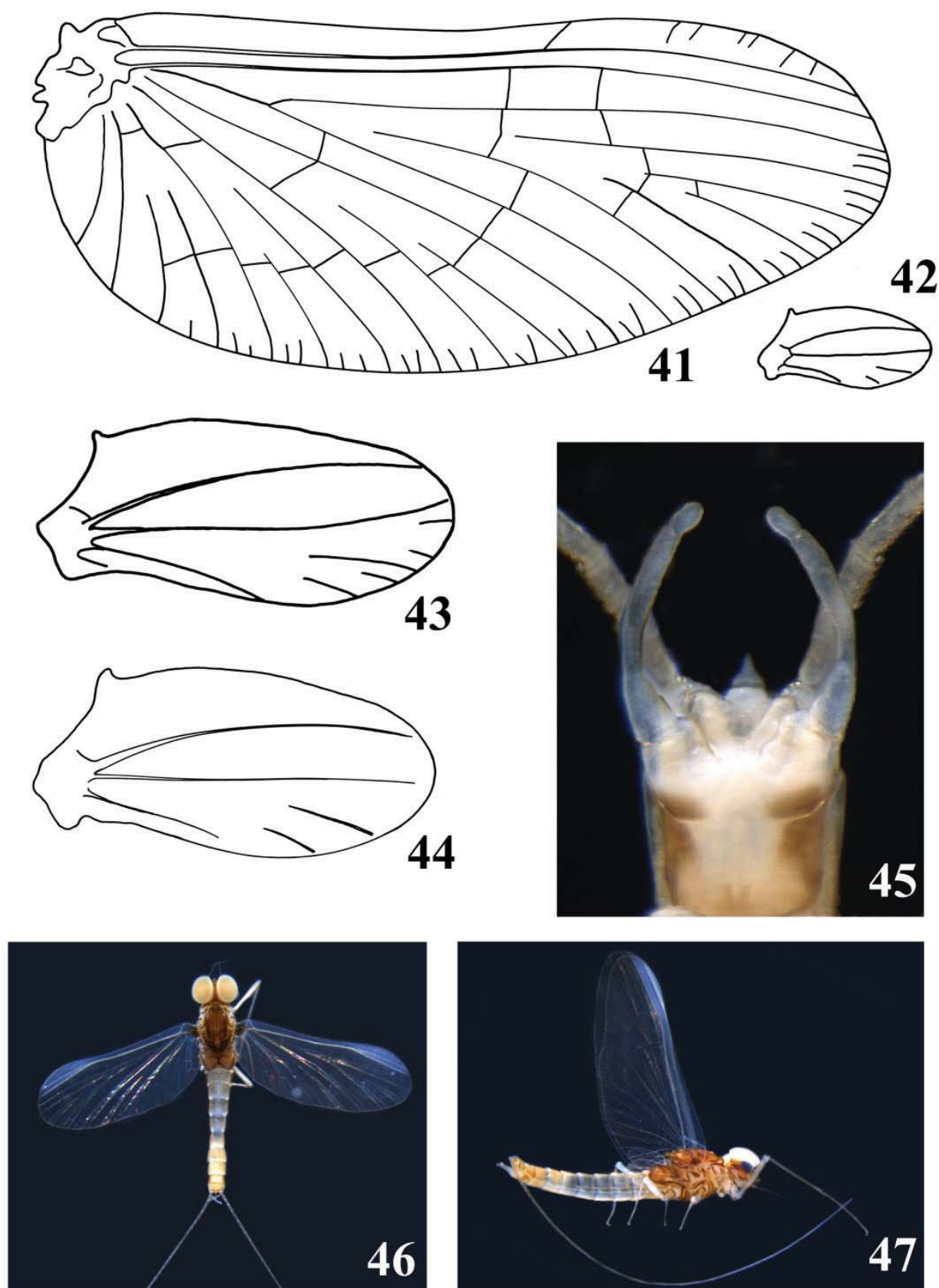
Figs 33-39. Larval structures of *Baetis monnerati* n.sp.: 33; foreleg. 34; tarsal claw. 35; ventral margin of forefemur. 36; dorsal margin of forefemur. 37a; gill IV. 37b; margin of gill IV. 38; distal margin of abdominal tergite IV. 39; paraproct.

– **Head.** Antennae with scape and pedicel covered with numerous short thin setae, without scales, scale bases or spatulate setae (Fig. 32); interantennal carina absent. Dorsal surface of labrum (Fig. 25) with one central seta and a distolateral row of 5-6 short to medium simple setae, abundant short fine setae scattered on the surface; ventral surface with three small pointed setae near lateral margin; distal margin with fringed setae. Hypopharynx (Fig. 26): lingua trilobed, covered with short thin setae; superlingua with thin setae apically and laterally. Right mandible (Fig. 27) with incisors composed of 7 denticles, outer denticle longer than others; prosthema without denticles, apex of inner margin with short thin setae; tuft of setae between prosthema and mola absent; tuft of setae at apex of mola present. Left mandible (Fig. 28) with incisors composed of 6 denticles; prosthema with 4 broad denticles and a comb-shaped structure; margin not crenelated between prosthema and mola and without setae; tuft of setae at apex of mola absent. Maxillae (Fig. 29) with 4 stout teeth;



Fig. 40. Larval structures of *Baetis monnerati* n.sp. (larva *in toto*).

lacinia with two rows of setae, one row with abundant small setae ending with stouter and longer setae, second row with 2 long stout dentisetae; 2 thin setae at base of teeth, row of 5 medium to long setae at base of lacinia; palp 2-segmented; segment I approximately 0.9 x length of segment II; segment II apically nipple-like, covered with thin setae. Labium (Fig. 31) with glossae shorter than paraglossae; inner and apical margins of glossae with long setae, ventral margin with 3 short setae; paraglossae falcate, apically with 3 rows of long setae, most apical seta shorter and very stout, a row of 5 medium setae apicolaterally; labial palp three-segmented; segment I 0.9 x length of segments II and III combined; segment II moderately expanded apicolaterally, with 6 medium setae roughly arranged in a row dorsally; segment III conical, elongated and slightly asymmetric, covered with medium stout setae and thin setae. – **Thorax.** Forelegs (Fig. 33). Trochanter bare. Femora dorsally with one row of more than 20 medium, stout, apically rounded setae, less abundant distally, tiny setae present along margin between medium setae, another row of tiny setae subparallel to dorsal margin (Figs. 33 and 36); dorsoapical setal patch formed by 2 enlarged apically rounded short setae; ventral margin with abundant tiny setae (Fig. 35); lateral margins almost bare. Tibiae dorsally with short thin setae; ventral margin with tiny pointed setae; lateral margins covered with abundant thin setae, scale bases absent, tibiopatellar suture present. Tarsi almost bare dorsally; ventral margin with about 12 pointed setae increasing in length toward apex; lateral margins covered with abundant thin setae, scale bases absent. Tarsal claws (Fig. 34) with one row of about 12 acute teeth increasing in length toward apex, pair of apical setae absent. Hindwing pads present. – **Abdomen.** Tergites shagreened, without scales or scale bases, distal margin with triangular spines, part of them blunt or bifid (Fig. 38). Sternites with abundant thin setae, without scales and scale bases; posterior margin smooth. Gills on segments I to VII elliptic and slightly serrated only along forward margin (Fig. 37b), tracheation poorly visible and almost not divided (Fig. 37a). Paraproct (Fig. 39) with abundant thin setae, scales only present close to distal margin, scale bases absent, margin with about 10 small to medium triangular spines; postero-lateral extension with a few thin setae, without scale bases, margin with 11-15 triangular small to medium spines.



Figs 41-47. Imaginal structures of *Baetis monnerati* n.sp.: 41; forewing. 42; hindwing (same magnification as forewing). 43-44; hindwing (high magnification) of two specimens. 45; male genitalia. 46; male imago (dorsal view). 47; male imago (lateral view).

Male imago. Length. Body: 4.2-5.1 mm; forewing 3.9-4.9 mm; hindwing 0.77-1.15 mm; foreleg: femur 0.71-1.07 mm, tibia 1.18-1.71 mm, tarsi T1 0.43-0.52 mm, T2 0.30-0.47 mm, T3 0.19-0.24 mm, T4 0.13-0.17 mm; cerci 9.2-10.4 mm. – **Colouration.** Head, scape, pedicel and flagellum medium brown. Facetted surface of compound eyes light brown, lateral face light brown with a brown ring at base. Thorax medium to dark brown. Legs medium brown without mark or stripe. Wings hyaline with medium brown venation. Abdomen: tergites medium brown with 2 or 4 darker brown spots (faintly visible on some specimens). Sternites uniformly light brown, except sternite IX dark brown laterally and ecru medially. Cerci medium brown (Figs 46-47). Genitalia light brown except base of the basal segment dark brown (Fig. 45). – **Forewing** (Fig. 41): pterostigma with about 6 cross-veins, generally not reaching subcostal vein; double intercalary veins shorter or slightly longer than half distance between corresponding main veins in proximal part of wing and longer than distance between corresponding main veins in distal part. – **Hindwing** (Figs 42-44) with an erect costal spur at 1/5 of the length of wing; 3 longitudinal veins reaching or almost reaching margin, 2 long incomplete veinlets between second and third main longitudinal veins, additional smaller incomplete veinlets present in some specimens. – **Genitalia** (Fig. 45): basal segment with inner margin expanded apicolaterally; segments I and II almost completely fused; segment I progressively narrower, without expansion or contraction; segment II with parallel margins; segment III ovoid, twice longer than broad.

Discussion

The *Baetis buceratus* species-group was originally defined by MÜLLER-LIEBENAU (1969) and was subsequently discussed by JACOB (2003). Recently, SOLDÁN & GODUNKO (2009) redefined this species-group using 22 characters at both larval and imaginal stages. *Baetis monnerati* perfectly matches all these 22 characters except character XIV (the surface is shagreened in *B. monnerati* without scale bases (Fig. 38), instead of with numerous scale bases as in other species of the *buceratus* species-group).

The *Baetis buceratus* species-group presently encompasses four species: *Baetis buceratus* Eaton, 1870, *B. pentaplebodes* Ujhelyi, 1966, *B. spei* Thomas & Dia, 1985 and *B. zdenkae* Soldán & Godunko, 2009. As mentioned above, *B. monnerati* clearly differs from these species by the absence of scale bases on the abdominal tergites (Fig. 38). The maxillary palp is wider in *B. buceratus*, *B. pentaplebodes* and *B. zdenkae* than in *B. spei* and *B. monnerati* (Fig. 31). The margin of the paraproct of *B. monnerati* has a reduced number of triangular spines (Fig. 39) compared to others species. The abdominal colouration of *B. monnerati* is less regular than in *B. buceratus*, *B. pentaplebodes* and *B. zdenkae*, with the tergites V, IX and X mostly ecru (MÜLLER-LIEBENAU 1969, THOMAS & DIA 1985, SOLDÁN & GODUNKO 2009). *B. buceratus*, *B. pentaplebodes* and *B. zdenkae* also possess gonopods more widely separate at the junction of the first and second segments than *B. monnerati* (SZIRAKI 2005, THOMAS & DIA 2007, SOLDÁN & GODUNKO 2009).

KOCH (1988) stated that *B. buceratus* is the most common mayfly in Northern Levant, and mentioned this species for the first time from Lebanon, Syria and Turkey. Part of these reports probably referred to *B. spei*, as KOCH did not seem to be aware of its description from Lebanon shortly before his contribution. We cannot exclude that another part of these reports, especially those from Israel, referred in fact to *B. monnerati*.

The sequenced specimens (three larvae GL2, GL4 and GL6 and two male imagos GL1 and GL5) proved to be undoubtedly conspecific as sequence divergence ranged from 0% to 2.2%, with one larva and one male imago sharing the same haplotype (0% divergence; Fig. 52). The divergence between 17 species of Palearctic *Baetis* ranged from 16.4% to 31.8%

(mean 23.8%; SROKA, in press), i.e. an order of magnitude greater than the maximum intra-specific divergence reported here. This gap between intra- and interspecific divergence has already been reported for mayflies (BALL et al. 2005). Consequently, there is no doubt that a maximum divergence of 2.2% reported for *B. monnerati* actually corresponds to intraspecific variation.

Etymology

This species is dedicated to Christian MONNERAT (CSCF, Neuchâtel, Switzerland) who collected all the examined material.

Procloeon pennulatum (Eaton, 1870)

Specimens examined. JO11: 6 larvae. Jordan; Wadi Rajib; 32°13'N, 35°42'E, 325 m a.s.l.; 8.viii.2009. – JO24: 2 ♂ imagos. Jordan; Wadi Ibn Hammad; 31°18'N, 35°38'E, 100 m a.s.l.; 17.xii.2010. All coll. C. MONNERAT.

Procloeon pennulatum is widespread in Europe, but generally localised and not abundant. This species is included in the Red List of some European countries and is considered as vulnerable, for example in Germany and Switzerland (MALZACHER et al. 1998, LUBINI et al. 2012). *P. pennulatum* also occurs in Lebanon and Syria (KOCH 1988). It is rare in Jordan streams, as it was only found at two localities.

This species can be recognised in the larval stage by the double gills with the lower plate elongate and asymmetric and the upper plate reduced (Figs 17e-f in BELFIORE 1983), the presence of hindwing pads, the length of median caudal filament subequal to cerci, the presence of lateral spines limited to the abdominal segments VIII and IX (Fig. 17a in BELFIORE 1983), and in the imaginal stage by the forewings with single intercalary veins, the narrow hindwings with a long and acute costal spur (Fig. 359 in BAUERNFEIND & HUMPECH 2001), genitalia with short and slender segment III and a trapezoid genital plate (Fig. 253 in STUDEMANN et al. 1992).

Cloeon dipterum (Linnaeus, 1761)

Specimens examined. JO1: 13 larvae. Jordan; Wadi Karak; 31°10'N, 35°41'E, 770 m a.s.l.; 7.iv.2009. Coll. C. MONNERAT.

Cloeon dipterum is the most common species of mayfly in European standing waters. It is mainly found in ponds and artificial channels but it can also colonise still parts of streams and rivers. *C. dipterum* is probably a complex of sibling species. However, no clear character allows the separation of the Jordan specimens from the Central Europe ones. This species is scarce in our samples, mainly because ponds were not prospected. It may prove to be common in Jordan. *C. dipterum* was collected in almost all the different areas of Turkey, Lebanon and Syria (KOCH 1988). Three other species of *Cloeon* were reported from the Arabian Peninsula: *Cloeon saharense* Soldán & Thomas, 1983 from Saudi Arabia (SARTORI & GILLIES 1990), *Cloeon arenorum* Gattolliat & Sartori, 2008 and *Cloeon vanharteni* Gattolliat & Sartori, 2008 from United Arab Emirates (GATTOLLIAT & SARTORI 2008). Furthermore, *Cloeon simile* Eaton, 1884 was reported from Syria and *Cloeon* sp. from Israel (KOCH 1988). The shape of the gills, the number of segments of the maxillary palp, the shape of the labial palp and the number of spines on lateral margins of the abdominal tergites

are the best characters to separate the different species of *Cloeon* in the larval stage (GATTOLLIAT & SARTORI 2008). The colouration and pattern of the hindwings and of the abdominal tergites are also useful to identify the female imagos (GATTOLLIAT & SARTORI 2008).

Cloeon dipterum differs from other species of mayflies collected in Jordan by the broad and almost rounded double lamellae of gills, spines on lateral margin of abdominal segments V to IX, the labial palp apically broad and truncated and the absence of hindwing pads. As mentioned, the spines on the lateral margin of abdominal segments are a reliable character to separate the different species of *Cloeon* from this area: *C. dipterum* has stout lateral spines on segments V to IX, while these spines are absent in *C. saharensis* and limited to segments VIII and IX in *C. vanharteni* and *C. arenorum*. The upper lamella of the gills is much more reduced in *C. vanharteni* than in *C. dipterum*. The labial palp is much more slender in *C. arenorum* than in *C. dipterum* (GATTOLLIAT & SARTORI 2008).

Caenidae

Four species of Caenidae, *Caenis macrura* Stephens, 1835, *Caenis antoniae* Malzacher, 1992, *Caenis gilbonensis* Malzacher, 1992, *Caenis parabrevipes* Malzacher, 1992, were reported from Israel by MALZACHER (1992) who provided a useful key to identify the larvae. The main characters are the shape of the IX sternite, the setation of the lateral margins of the abdomen and the degree of development of the posterolateral extension of the abdominal segments (referred to as spines of the hind corners of the abdominal segments in MALZACHER 1992). Three species were also reported from the Arabian Peninsula: *Caenis corana* Thomas & Sartori, 1989, *Caenis luctuosa* (Burmeister, 1839), *Caenis malzacheri* Sartori & Gattolliat, 2008, which could also occur in Jordan (THOMAS & SARTORI 1989, GATTOLLIAT & SARTORI 2008). In the material examined, only *C. antoniae* and *C. parabrevipes* were discovered. According to MALZACHER (1992), these two species are related to Afrotropical species.

Caenis antoniae Malzacher, 1992

Specimens examined. JO1: 4 larvae. Jordan; Wadi Karak; 31°10'N, 35°41'E, 770 m a.s.l.; 7.iv.2009. – JO2: 11 larvae. Jordan; Wadi Karak; 31°10'N, 35°41'E, 775 m a.s.l.; 7.iv.2009. – JO5-8: 18 larvae. Jordan; Wadi Mujib, close to Dead Sea; 31°27'N, 35°34'E, -381 m alt.; 7.iv.2009. – JO10: 3 larvae. Jordan; Wadi Kufrinja; 32°16'N, 35°37'E, -65 m b.s.l.; 6.viii.2009. – JO15: 11 larvae. Jordan; Wadi Siyyagh upstream (near Wadi Musa); 30°19'N, 35°25'E, 855 m a.s.l.; 16.viii.2009. – JO21: 1 larva. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 75 m a.s.l.; 15.xii.2010. – JO25: 16 larvae. Jordan; Wadi Ibn Hammad; 31°17'N, 35°41'E, 525 m a.s.l.; 17.xii.2010. – JO26: 3 larvae. Jordan; Wadi Ibn Hammad; 31°16'N, 35° 41'E, 525 m a.s.l.; 17.xii.2010. – JO27: 5 larvae. Jordan; Wadi Ziglab/ Al Qulai'at; 32° 31'N, 35°37'E, -115 m b.s.l.; 22.xii.2010. All coll. C. MONNERAT.

This species, described and only known from a tributary of the Dead Sea, is quite common and widely distributed in Jordan. In some of the localities, it co-occurs with *C. parabrevipes*. *C. antoniae* can be easily distinguished from other species of the genus, and especially from *C. parabrevipes*, by the deep emargination of the IX sternite and the long and abundant setae on the lateral margin of abdominal segments (MALZACHER 1992). As noted in the original description, the size of full-grown larvae is highly variable between and among populations (MALZACHER 1992).

Caenis parabrevipes Malzacher, 1992

Specimens examined. JO5-8: 9 ♂ larvae. Jordan; Wadi Mujib, close to Dead Sea; 31°27'N, 35°34'E, -381 m b.s.l.; 7.iv.2009. – JO19: 3 larvae. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 45 m a.s.l.; 11.xi.2009. – JO20: 10 larvae. Jordan; Wadi Hasa; 31°59'N, 35°39'E, 235 m a.s.l.; 12.xi.2009. – JO21: 1 larva. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 75 m a.s.l.; 15.xii.2010. All coll. C. MONNERAT.

In Jordan, *Caenis parabrevipes* is less common and less abundant than *C. antoniae*. It can be identified by the short posterolateral extension of the abdominal segments, small and shallow indentation of the IX sternite, and the tergites VIII and IX with a restricted number of medium setae (MALZACHER 1992).

Leptophlebiidae

Choroterpes (Euthraulius) ortali Sartori, 1992

Specimens examined. JO19: 3 larvae. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 45 m a.s.l.; 11.xi.2009. – JO21: 21 larvae. Jordan; Wadi Weida'a (East Mazzra'a); 31°14'N, 35°35'E, 75 m a.s.l.; 15.xii.2010. – JO24: 2 ♂ imagos. Jordan; Wadi Ibn Hammad; 31°18'N, 35°38'E, 100 m a.s.l.; 17.xii.2010. All coll. C. MONNERAT.

This species was described from a tributary of the Dead Sea area, where it was relatively abundant, but was not found in nearby watercourses (SARTORI 1992) and has not been mentioned since then. The Jordan specimens, both larvae and adults, perfectly fit the descriptions provided by SARTORI (1992). In the adult stage, the general colouration of the abdominal tergites, maculation on the legs, fore- and hindwing venation and above all the shape of the genital forceps, penis and penis armature (Figs 50-51) are identical between specimens from Israel and Jordan. In the larval stage, the only difference can be found on the glossae, which are regularly rounded in the Israel population and rhomboidal in the Jordan ones. One character unique among the Palearctic species of *Choroterpes (Euthraulius)*, which was overlooked by SARTORI (1992), is the shape of the tarsal claw. The denticles are in two groups, a basal one of 4-6 increasing in size, then a proximal one longer (Fig. 48).

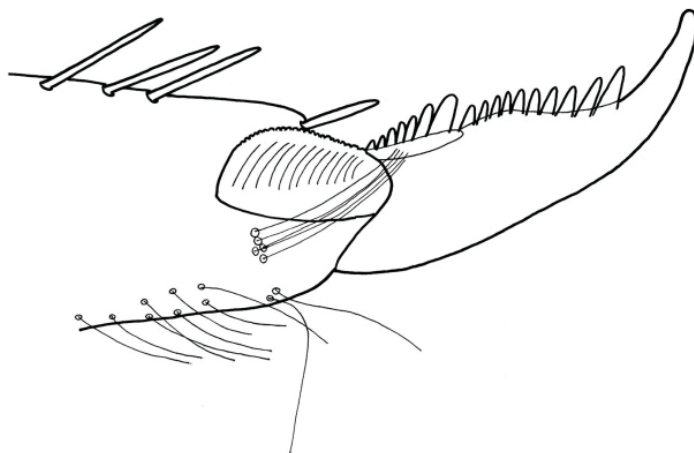
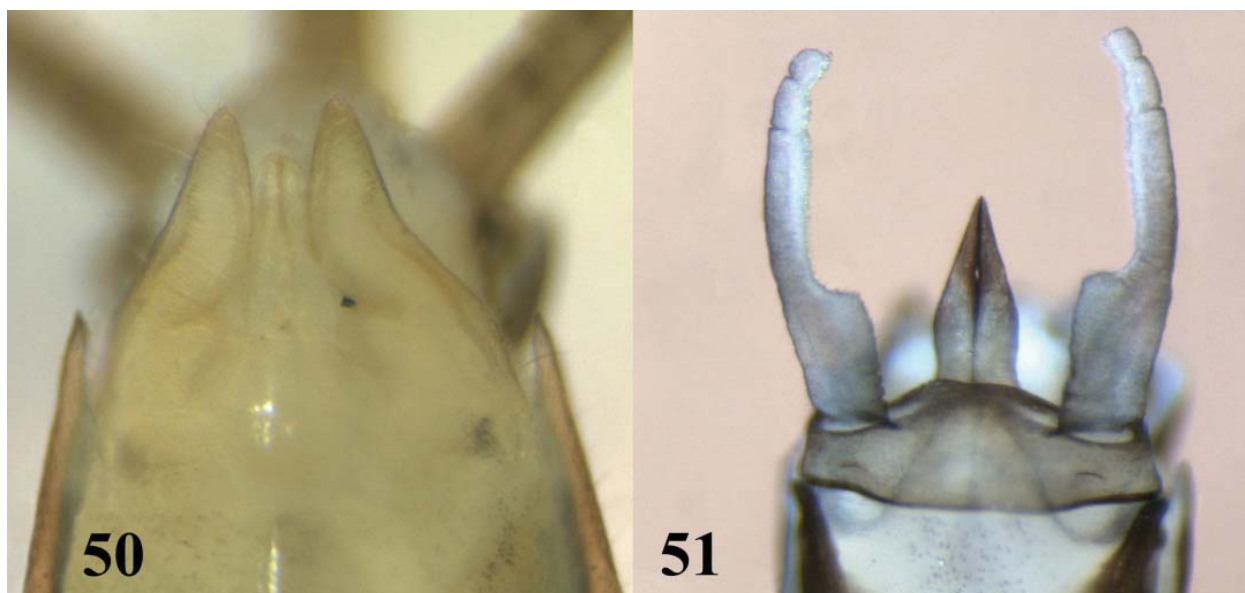


Fig. 48. Larval structures of *Choroterpes (Euthraulius) ortali*: tarsal claw.



Fig. 49. Larval structures of *Choroterpes (Euthraulius) ortali*: male larva *in toto*.



Figs 50-51. Larval and imaginal structures of *Choroterpes (Euthraulius) ortali*: 50; genitalia of male subimago under larval cuticle. 51; male imago genitalia.

This character is not present in *Ch. (Eu.) arabica* for instance, nor in any other related species where the denticles are regularly arranged and increase in size. Only some Oriental species of the subgenera *Euthraulius* and *Cryptopenella*, as well as some species of the genus

Choroterpides present this character (PETERS & EDMUNDS 1964, KANG & YANG 1994, ZHOU 2006). From a geographic point of view, both populations occur at a distance of *ca.* 30 km on each side of the Dead Sea.

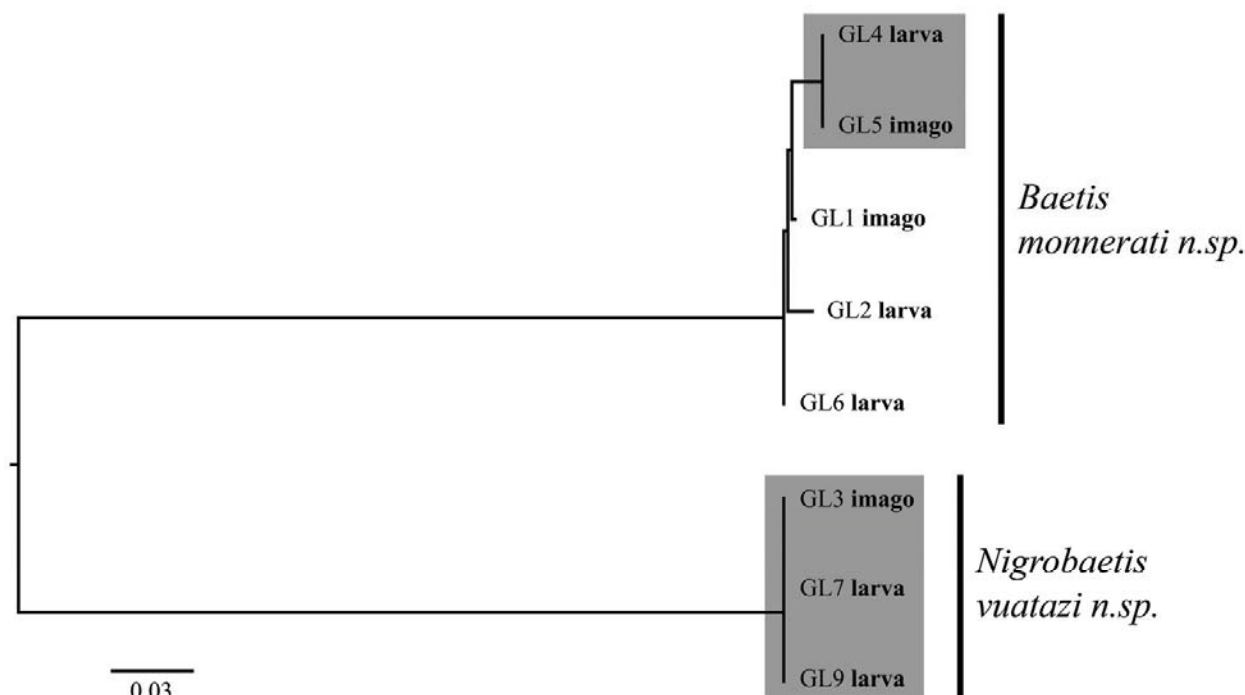


Fig. 52. Maximum Likelihood COI tree of the eight sequenced specimens. Dark grey shading highlights identical haplotypes.

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