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SARI, NECMETTİN; KÜLKÖYLÜOĞLU, OKAN; and AKDEMİR, DERYA (2012) "First record and detailed description of the male of Ilyocypris inermis Kaufmann, 1900 (Crustacea, Ostracoda)," *Turkish Journal of Zoology*. Vol. 36: No. 4, Article 8. https://doi.org/10.3906/zoo-1012-78
Available at: https://journals.tubitak.gov.tr/zoology/vol36/iss4/8

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First record and detailed description of the male of 
*Ilyocypris inermis* Kaufmann, 1900 (Crustacea, Ostracoda)

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Received: 30.12.2010

Abstract: Bisexual populations of *Ilyocypris inermis* Kaufmann, 1900 were reported for the first time from 5 different aquatic bodies in Bolu and Erzincan (Turkey). The males were compared with the males of the other 11 species of the genus *Ilyocypris* (*I. australiensis*, *I. biplicata*, *I. decipiens*, *I. dentifera*, *I. divisa*, *I. fallax*, *I. getica*, *I. gibba*, *I. lacustris*, *I. mongolica*, and *I. monstirifica*) and described based on examinations of the soft body parts (e.g., hemipenis, legs, clasping organs) and valves. Ecological characteristics of habitats where the bisexual populations found were discussed for future studies.

Key words: Taxonomy, morphology, bisexual population, distribution, Anatolia

*Ilyocypris inermis* Kaufmann, 1900 (Crustacea, Ostracoda) erkekinin ilk kez rapor edilisi ve detayli tanimlanmasi


Anahtar sözcükler: Taksonomi, morfoloji, biseksüel populasyon, dağılım, Anadolu

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Introduction

Ostracods, having sexual, asexual, and mixed modes of reproduction (both bisexual and parthenogenetic reproductive types are usually geographically segregated, although females of both types can occur sympatriically), are remarkable aquatic invertebrates in Crustacea (Butlin et al., 1998). Of these, some populations (e.g., *Potamocypris villosa*, *Cavernocypris subterranea*, *Pseudocypridopsis clathrata*, and *Eucypris virens* (Martens and Meisch, 1985; Külköylüoğlu and Vinyard, 1998; Karanovic, 1999; Bode et al., 2010, respectively)) can have males with limited geographical distribution in certain types of habitats. Such reproductive modes may depend on several factors of evolutionary and/or ecological characteristics of species (Gülen, 1985; Cohen and Morin, 1990; Little and Hebert, 1994; Martens, 1998). It is probable that these modes increase the survival chance of species in different types of habitats, extending their geographical distribution and diversity. Although several views have been proposed to explain the wide distribution of sexual populations in different taxonomic groups (e.g., see Lewis, 1987; Jan et al., 2000), the reason(s) for the relatively small quantity and scarce existence of male ostracods compared to females remains unclear. Currently, more than 45 bisexual ostracod species are known in Turkey, several of which were once known only with parthenogenetic reproduction from different geographical locations (Gülen, 1985; Külköylüoğlu and Yılmaz, 2006). We present herein the males of *Ilyocypris inermis* from 5 different locations of Turkey and provide detailed morphological description. Although limited, these findings extend the geographical distribution of the species as well as our knowledge about the species’ habitat preferences.

Materials and methods

Samples collected from 5 stations in 2 provinces (Bolu and Erzincan) in Turkey (Figure 1) with a hand net (250 μm in mesh size) were fixed in 70% alcohol in plastic containers (250 mL). In the laboratory, the material was washed in 3 standardized sieves (1.0, 0.5, 0.25 mm mesh size, respectively) under tap water. All species were preserved in 70% ethanol. Drawings of the species were done with a camera lucida attached to an Olympus BX-51 binocular microscope. Carapace and valves were photographed with a scanning electron microscope (Jeol/JSM 6335F, SEM). Other valves were kept in micropalaeontological slides.

The species taxonomy and identification followed by Kempf (1997) and Meisch (2000) was based on the soft body parts and carapace of adult individuals. We used the model described by Broodbakker and Daniellopol (1982) for chaetotaxic notation including revision for the second antenna (Martens, 1987) and the thoracopods (Meisch, 1996), while the names of the limbs were adapted from Meisch (2000). Daniellopol’s (1969) nomenclature was used for the hemipenis morphology. The lengths of podomeres, used as reference for evaluation of the relative length (L) of setae and claws of a given limb, were measured in the middle of the podomeres (Namiotko et al., 2005). The environmental variables (pH, water temperature (Tw), electrical conductivity (EC), dissolved oxygen (DO), redox potential (Eh), percent oxygen saturation (%S), salinity (Sal.)) were measured in situ. A Hanna model HI-98150 pH/ORP meter was used to measure pH and redox potential (Eh) and a YSI-85 model oxygen-temperature meter was used to measure the remaining variables. Air temperature values were provided by the Meteorological Station Centers in Bolu and Erzincan. Redox potential was transformed to Standard Hydrogen Electrode (SHE, mV). Total dissolved solid (TDS) values were found by multiplying EC with 0.65. Geographical data (altitude, latitude, longitude) were obtained with a global positioning system (GPS 12 XL) (Table 1). All specimens are stored in the Limnology Laboratory of the Biology Department (Bolu, Turkey).

Abbreviations used in the text, tables, and figures

A - anterior; a - outer lobe of hemipenis; A1 - antennule; A2 - antenna; b - inner lobe of hemipenis; cs - chelate seta; D - distal; d - seta on Pr of L6; d1, d2, dp - setae on Pr of L7; E - endopod; e - setae on EI of L6 and L7; Ex - exterior; Exo - exopod; f - setae on EII of L6 and L7; Fu - furca (= uropod); g - setae on EIII of L6 and L7; G - claw; Ga - anterior claw of Fu; G1-3 - anterior and internal claws (or setae) on EIII of A2; H - height; h - medial lobe of hemipenis; h1-3 - setae (or claws) on EIV of L6 and L7; In - interior;
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L - length; l - large (relative L of setae or claws); L5 - maxilliped (5th limb); L6 - walking leg (6th limb); L7 - cleaning leg (7th limb); LV - left valve; m - medium (relative L of setae or claws); Md - mandible (3rd limb); Mdp - mandibular palp; Mx1 - maxillule (4th limb); P - posterior; Pr - protopod; RV - right valve; s - small (relative L of setae or claws); sa (sp) - anterior (posterior) seta of Fu; S1-2 - plumed cleaning setae on the 1st podomere of Mdp; t1-4 - internal setae on EII of A2; W - width; Y - aesthetasc on EI of A2; y1-3 - aesthetascs on EII, EIII and EIV of A2, respectively; ya - aesthetasc on the terminal podomere of A1; z1-3 - external setae on EII of A2; α, β, γ - special setae on the 1st, 2nd, and 3rd podomeres of Mdp, respectively.

**Results**

Bisexual populations of *Ilyocypris inermis* (15 males and 65 females) and accompanying taxa were found at 5 stations (2 in Bolu (stations 23 and 30) and 3 in Erzincan (stations 9, 11, and 57)) (Figure 1). St. No. 9 (unnamed spring): *Ilyocypris inermis*, 1♂; *Ilyocypris bradyi*, 2♀; *Psychrodromus olivaceus*, 1♀. St. No. 11 (an irrigation canal): *Ilyocypris inermis*, 5♂, 42♀; *Heterocypris incongruens*, 17♀; *Candona neglecta*, 1♂, 2♀. St. No. 23 (unnamed creek): *Ilyocypris inermis*, 1♂, 7♀; *Prionocypris zenkeri*, 1♀; *Candona neglecta*, 1♀; *Psychrodromus fontinalis*, 2♀; *Potamocypsis similis*, 60♀. St. No. 30 (a slow running creek): *Ilyocypris inermis*, 7♂, 12♀; *Candona neglecta*, 3♀; *Potamocypsis similis*, 45♀. St. No. 57 (irrigation canal): *Ilyocypris inermis*, 1♂, 4♀; *Ilyocypris bradyi*, 6♀; *Psychrodromus fontinalis*, 52♂, 53♀. The species was generally found in slow flowing areas of canals and creeks with relatively low levels of dissolved oxygen at different elevations (700 to 1553 m a.s.l.) where water temperature varied between 13 and 22 °C (Table 1).

**Taxonomic descriptions**

*Phylum Arthropoda*

*Subphylum Crustacea Pennant, 1777*

*Class Ostracoda Latreille, 1806*

*Subclass Podocopa Müller, 1894*

*Order Podocopida Sars, 1866*

*Suborder Podocopina Sars, 1866*

*Infraorder Cypridocopina Jones, 1901*

*Family Ilyocyprididae Kaufmann, 1900*

*Subfamily Ilyocypridinae Kaufmann, 1900*

*Genus Ilyocypris Brady and Norman, 1889*

*Ilyocypris inermis* Kaufmann, 1900

**Sampling site.** - Turkey, northern Bolu, Göynük County, an unnamed slow running creek (St-30) close to Boyalıköy village (40°24′53″N 30°45′20″E), altitude 708 m; 7 males and 12 females were collected on 27 June 2006, and kept in 70% ethanol. An additional 8 individuals were also collected from station 23 on the same day. The rest of the individuals were collected from stations 9 and 11 (26 July 2006) and 57 (11 August 2006) in Erzincan.
Table 1. Measurements of 10 variables and geographical data (altitude, latitude, longitude) of 5 stations (St. type) where males of *I. inermis* were found along with the accompanying species. Abbreviations: pH; SHE, standard hydrogen electrode (mV); DO, dissolved oxygen (mg/L); EC, electrical conductivity (μS/cm, at 20 °C); TDS, total dissolved solids (mg/L); %S, percentage oxygen saturation (mg/L); T(w), water temperature (°C); T(a), air temperature (°C); Sal, salinity, (ppt); Alt, altitude (m a.s.l.). Species codes: II, *Ilyocypris inermis*; IB, *I. bradyi*; PO, *Psychrodromus olivaceus*; PF, *P. fontinalis*; HI, *Heterocypris incongruens*; CN, *Candona neglecta*; PZ, *Prionocypris zenkeri*; PS, *Potamocypris similis*.

<table>
<thead>
<tr>
<th>St. no.</th>
<th>City name</th>
<th>St. type</th>
<th>pH</th>
<th>SHE</th>
<th>DO</th>
<th>EC</th>
<th>TDS</th>
<th>%S</th>
<th>T (w)</th>
<th>T(a)</th>
<th>Sal</th>
<th>Alt</th>
<th>Latitude/longitude</th>
<th>Species code</th>
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<tr>
<td>9</td>
<td>Erzincan</td>
<td>Spring</td>
<td>6.76</td>
<td>199.02</td>
<td>4.62</td>
<td>547</td>
<td>355.55</td>
<td>48</td>
<td>16.5</td>
<td>27.3</td>
<td>0.0</td>
<td>966</td>
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<td>11</td>
<td>Erzincan</td>
<td>Irrigation canal</td>
<td>7.32</td>
<td>195.92</td>
<td>5.83</td>
<td>498.5</td>
<td>324.02</td>
<td>60.1</td>
<td>16.5</td>
<td>27.3</td>
<td>0.2</td>
<td>1425</td>
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<td>II, HI, CN</td>
</tr>
<tr>
<td>57</td>
<td>Erzincan</td>
<td>Irrigation canal</td>
<td>7.46</td>
<td>182.54</td>
<td>4.54</td>
<td>870</td>
<td>565.5</td>
<td>51.9</td>
<td>21.7</td>
<td>28.8</td>
<td>0.4</td>
<td>1553</td>
<td>40°35′30″N 39°37′25″E</td>
<td>II, IB, PF</td>
</tr>
<tr>
<td>23</td>
<td>Bolu</td>
<td>Creek</td>
<td>8.02</td>
<td>153.44</td>
<td>7.63</td>
<td>326.2</td>
<td>212.03</td>
<td>72.9</td>
<td>13.1</td>
<td>19.6</td>
<td>0.2</td>
<td>894</td>
<td>40°24′53″N 30°45′20″E</td>
<td>II, CN, PS</td>
</tr>
</tbody>
</table>

Material examined. -We thought that type specimens do not exist so far. Thus, the soft body parts of a male were dissected in lactaphenol and valves were kept in a micropalaeontological slide (II-001). The soft body parts of a female were dissected in lactaphenol (Ii-002). The soft body parts of the mounted individuals (2 males and 2 females) were kept in micropalaeontological slides (II-003, II-004), and the remaining kept in 70% ethanol. Four males and 9 females collected from the type locality and kept in 70% ethanol are deposited in the limnology laboratory of the Biology Department (Hydrobiology subsection), Abant İzzet Baysal University, Bolu, Turkey.

Diagnosis of male *Ilyocypris inermis*

Males (RV: L: 0.92 mm, H: 0.42 mm - LV: L: 0.94 mm, H: 0.44 mm) slightly smaller than females (L: 1.014 mm H: 0.448 mm). Color is whitish. Six natatory setae of second antenna reduced, the longest setae barely reaching half of the second segment. Distal segment of mandibular palp with a small dorso-median seta—this seta is not seen in the males of the other species of the genus. Inner (dorsal) and outer (ventral) lobes of hemipenis are almost equal in size.

Description of male

Anterior and posterior margins of the valves smooth; valves with 2 well developed dorso-median sulci; dorsal margin almost straight; anterior end of carapace slightly beak-shaped and posterior end roundly spindle-shaped in dorsal view; LV overlaps RV at both ends; surface of valves covered with small circular pits (Figures 2A-E).

A1 7-segmented (Figure 3A). I: A-1m, P-2l / II: A-1m / III: A-1m / IV: A-2l, P:1l-1s / V: A-2l, P-1l-1m(pa) / VI: A-2l, P-Il-Il(l/lu) / VII: D-γ-1l(cs)-1l.

A2 4- segmentend endopodite (Figure 3C). Pr: P-1l, EXO: 1l-2s / EI: P: 1s(Y), D(P)-1l, D(In)-6s / EII: P-1s(y1)-4s(1-4), A-2s, D(P)-1s (y2), D(Ex)-1s (G3)-2s(z2-3)-1m(z1:G), D(A)-1l (G2:G), D(In)-1l (G1:G) / EII: D(A)-1l (GM:G), D(P)-1s(y3)-1s(g), D(Ex)-1l(Gm:G). Note to sexual dimorphism in female (Figure 3B).

Md: (Figure 4A). Mdp (Masticatory part of coxa): distally with 7 stout teeth and ventrally with 1 plumbed seta. I: I (α)-1s(S2)-1m-1m(S1) / II: Ex-2l(pl), In-1l-3m-3m(setal group) / III: Ex-2m-2l, In-1l-2m, D-1m(y) / IV: D-3l(G)-1s-1s (dorso-median).

Mxl (maxillula) (Figure 4B). No specific features recognized.
L5 (first thoracopod) (Figures 4C, D). Right and left clasping organs are subequal and elongated, bearing 1 sensory seta. One apical seta extends about the size of terminal segment, which is slightly swollen antero-ventrally.

L6 (walking leg) (Figure 5A). Pr: A-Is(d) / EI: A(D)-Is(e) / EII: A(D)-Is(f) / EIII: A(D)-2s(g) / EIV: P-Is(h3), D-Is(h1)-II(h2:G). Terminal claw (h2) about 2.9 × L of EII.
Figure 3. *Ilyocypris inermis*. A. A1 of male. B. Distal end of A2 of female. C. A2 of male. Scale bar: 71 μm for A; 42 μm for B; 62 μm for C.

Figure 4. *Ilyocypris inermis* (male). A. Mandible. B. Maxillula (Mxl). C, D (L5) Right and left claspers organs. Scale bar: 57 μm for B; 80 μm for C; 91 μm for D. Note the arrow head, which shows a smooth seta found in the last segment of male mandible.
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L7 (cleaning leg) (Figure 5B). Pr: Ex-II(d1) / EI: P-II(e) / EII: P-Im(f)-II(g) / EIII: D-3l(h1,h2,h3:ser). Relative L of 3 apical setae as: h1 = 1.5×, h2 = 1.3×, h3 = 1.9 L of EI.

Hemipenis (Figures 6A, B). Outer lobe (a) ventrally broad, rectangular, inner lobe (b) distally slightly enlarged, club-shaped, medial lobe (h) is the longest, partly overlapping inner lobe, triangular. Inner and outer lobes of hemipenis are almost equal in size.

Zenker’s organ (Figure 6C) with about 16 internal spinous whorls.

Furca (Figure 6D): Furcal ramus is well developed, 1 short distal seta (sa; ca. 1/5 of Ga), 1 apical (Ga) and 1 subapical (Gp) claw and 1 posterior seta (sp is equal to 0.7 × L of Ga). There are tiny spinules in posterior margin especially between sp and Gp.

**Discussion**

The subfamily *Ilyocypridinae* Kaufmann, 1900 includes only a single genus, *Ilyocypris*. Kempf (1980, 1997) lists about 230 species and the Global Name Index (2010) gives about 192 extinct and extant species of the genus, worldwide. Most species are fossils and there are about 30 recent species in the world, 11 of which are known from Europe (Meisch, 2000). In Turkey, 11 species (*Ilyocypris biplicata*, *I. bradyi*, *I. brehmi*, *I. decipiens*, *I. divisa*, *I. getica*, *I. gibba*, *I. hartmanni*, *I. inermis*, *I. monstrifica*, *I. salebrosa*) have been reported so far. Based on previous works (Victor and Fernando, 1981; Martens, 1991), it is pinpointed that *I. turca* and *I. angulata* are junior synonyms of *I. brehmi* and *I. dentifera*, respectively. We accept this view. Although the discussion goes on (Sars, 1928; Van Harten, 1979; Meisch, 2000), we at the moment accept that *I. biplicata* and *I. gibba* are 2 different species because of differences in the carapace structures (Janz 1994) and some fine details in their soft body parts. The fact is that the taxonomic positions of *Ilyocypris* species are problematic (Meisch, 1988; Martens, 1991): *I. inermis* differs from the other species discussed below. Herein, we re-examined 17 of those species that we had knowledge about based on the carapace (presence or absence of lateral tubercles) and soft body parts (A2, L6, L7, hemipenis) (Tables 2 and 3), which are commonly used for taxonomic description as diagnostic characteristics of the genus.
In male *I. inermis*, carapace lacking lateral tubercles carry weakly developed small ripples on the posteroventral margins (also see Janz 1994). In contrast, at least 3 of the species compared with males (e.g., *I. decipiens*, *I. gibba*, *I. monstrifica*) either having with well developed lateral tubercles and/or marginal ripples differ from *I. inermis*. Comparing the length of the carapace, one may notice that the length of the species examined here ranges from 0.70 to 1.25 mm. Since the range overlaps with that of several species, we consider that size may not be a good diagnostic character for the species but an exception may occur in a small-sized (0.51 mm of length) species, *I. nagamaliensis* (Victor and Fernando, 1981). The length of the swimming setae on A2 is another important characteristic: *I. inermis*, having short (or reduced) setae, differs from all other species discussed here, except *I. bradyi*. In *I. inermis*, these setae are very short, barely reaching half of the segment EII, while the setae may extend to the base of the terminal claws in *I. bradyi*.

The penultimate segment of the walking leg (L6) is divided in *I. inermis* but this segment is undivided in the males of *I. australiensis*, *I. biplicata*, *I. dentifera*, *I. gibba*, *I. lacustrist*, and *I. fallax*. Except 2 (*I. getica* and *I. lacustrist*), all species including *I. inermis* examined here have 2 setae on the cleaning legs (L7), whose length can vary.

The number of whorls in Zenker’s organ is 16 in the males of *I. inermis*, which differs from the other species, except 2: *I. monstrifica* (with 16-20 whorls) and *I. biplicata* (with 16-18 whorls). The hemipenis of *I. inermis* shows difference in fine details; for instance,
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the outer lobe (a) ventrally broad, rectangular; inner lobe (b) distally slightly enlarged, club-shaped; the medial lobe (h) is the longest, partly overlapping the inner lobe, triangular (Table 3).

It should be mentioned that the inner and outer lobes are almost equal in size in *I. inermis* but this shows differences in the other species, in which mostly the inner lobe is longer than the outer lobe (Table 3). Although some differences occur in the shape and size of the hemipenis, description of the species based on the hemipenis is recommended, at the moment. However, Martens (1991), introducing *I. mongolica* as a new species from Mongolia, proposed to use the stylus in the copulatory process as a new taxonomic characteristic along with the hook-like structures on L7. Martens (1991) stated that the stylus was long, narrow, bluntly pointed, and slightly sinuous sclerified in *I. mongolica*, similar to *I. getica*, but rounded in *I. australiensis* and curved in *Ilyocypris* spec. sp. n. This structure is slightly S-shaped in *I. inermis*. Moreover, there are no hook-like structures on L7 in *I. inermis* but 4-6 structures were described in *I. mongolica*. As mentioned earlier (Victor and Fernando, 1981; Meisch, 1988, 2000), urgent revision is needed for the taxonomic status of *Ilyocypris* species.

Griffiths (2001) pointed out that many species of the genus show geographical parthenogenesis,
usually distributed in the southern parts of their ranges. In addition, among the large numbers of chronospecies, some (e.g., *I. steegeri*) show a narrow distribution in highly local areas. A similar pattern of distribution is also evident for some other species and this may correspond with their reproductive modes. For example, sexual populations of *Eucypris virens* are known to be found in the circum-Mediterranean habitats when asexual populations seem to be distributed in Europe (Horne et al., 1998). However, the distribution of parthenogenetic populations of *E. virens* extends to the far east of Anatolia (Külköylüoğlu, O., unpublished data). According to some previous studies (Gülen, 1985; Griffiths, 2001) finding rare males (or bisexual populations) of some species more in Anatolia or in southeastern Europe is not actually surprising since these populations have been migrating to/from Europe. This may coincide with the warm climatic changes (Griffiths, 2001) but also imply high genetic diversity and species richness in Turkey. As mentioned above, we found the males of *I. inermis* in springs, canals, and creeks with relatively low flow. This shows that this species is possibly bottom-dependent. Indeed, the lack of swimming setae on the second antenna may also support this view. Thus, such dependency may limit its active distribution from site to site, but flowing waters may help in their passive dispersion. As shown in Table 1, except electrical conductivity (326.2–870 μS/cm), the ecological conditions of those habitats where the bisexual populations were found were within the range of freshwater environments. Although the relatively high conductivity value may be related to its wide range of tolerances to conductivity, the results

<table>
<thead>
<tr>
<th>Species name</th>
<th>Parts of hemipenis</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I. australiensis</em></td>
<td>shorter, reaching about 1/3 of inner lobe, ventrally broadened, bluntly pointed</td>
</tr>
<tr>
<td><em>I. biplicata</em></td>
<td>ventrally broadened, bluntly pointed</td>
</tr>
<tr>
<td><em>I. decipiens</em></td>
<td>short, about 1/3 of inner lobe, thin, bluntly pointed</td>
</tr>
<tr>
<td><em>I. dentifera</em></td>
<td>short, ventrally broadened, bluntly pointed</td>
</tr>
<tr>
<td><em>I. divisa</em></td>
<td>slightly shorter than inner lobe, both lobes bluntly pointed</td>
</tr>
<tr>
<td><em>I. getica</em></td>
<td>similar to <em>I. lacustris</em></td>
</tr>
<tr>
<td><em>I. gibba</em></td>
<td>ventrally broadened, slightly longer than outer lobe, curved and bluntly pointed</td>
</tr>
<tr>
<td><em>I. lacustris</em></td>
<td>about equal in size with inner lobe, distally broadly rounded, about equal in size with distal lobe</td>
</tr>
<tr>
<td><em>I. mongolica</em></td>
<td>ventrally broadened, bluntly rectangular pointing, longer than outer lobe</td>
</tr>
<tr>
<td><em>I. monstrifica</em></td>
<td>ventrally broadened, bluntly pointed with triangular shape, slightly longer than outer lobe, distally oval</td>
</tr>
<tr>
<td><em>I. fallax</em></td>
<td>about 1/3 of inner lobe, curved, bluntly pointed</td>
</tr>
<tr>
<td><em>I. inermis</em></td>
<td>ventrally broadened, rectangular, almost club-shaped, same in length, distally slightly enlarged, longest, triangular, internally directed point</td>
</tr>
</tbody>
</table>
based on one sampling from that location should not be generalized at the moment. Hence, our knowledge of the species’ ecological preferences is insufficient.

Remarks: (a) We recognized the presence of a small dorso-median seta on the distal segment of the mandibular palp (Figure 4A) in *I. inermis*. This structure has not been seen in other species of the genus and can be used as a new taxonomic feature. (b) Generally, there are 2 setae on the trunk of the clasping organs in *Ilyocypris*, but there is 1 seta in *I. inermis*, except for 1 male specimen from Erzincan, which has a very tiny ventrally located seta. Based on the drawings by Brehm (1929), *I. fallax* bears 1 seta as well. (c) Most recently, Martens and Savatentalinton (2011) listed 34 recent species of *Ilyocypris* within a subjective checklist. However, the present paper was accepted before their work was published. Therefore, we were not able to include their valuable work in our discussion.

Acknowledgements

We would like to thank Gıyasettin Sari for his help during field sampling. Thanks are also due to Orhan İpek and Cem Berk (TÜBİTAK-MAM) for their assistance in SEM photographing.

References


