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# Notes on the distribution of the genus *Artemia* in the former USSR countries (Russia and adjacent regions)

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In this study we review the Russian literature on *Artemia* distribution in several saline lakes and ponds of former USSR, and report on the results of our studies for a number of populations, aiming to update available information and to identify species, often erroneously designated as *A. salina* in the existing literature. Most of the populations recorded/examined belong to parthenogenetic *Artemia* while a number of bisexual populations were also found. The morphology of the basal part of penis, investigated by means of SEM revealed that not all of these bisexuals belong to the species *A. salina*, known to occur only in the Mediterranean area. The males of some populations are characterized by the presence of a spine-like outgrowth at the basal part of the penis, a character shared by all bisexuals but Mediterranean. More detailed SEM morphological studies of the frontal knobs and the eversible penis reinforced biomolecular and morphometrical data will certainly contribute to species identification. The need for extensive sampling of the territory is stressed to bridge the gap about *Artemia* distribution and status in the countries of former USSR.

**Key words:** *Artemia* sp., parthenogenetic, distribution, saline lakes, former USSR.

## INTRODUCTION

Despite the information made recently available on *Artemia* biodiversity for Eastern Europe and South East Asia a considerable gap still exists for former Soviet Union countries. This is mainly due to the fact that most of the existing literature is in Russian, hence not accessible to a large part of the scientific community.

Initial information on the presence of *Artemia* in former USSR dates back to 1970s, and it is limited only to some regions of this vast territory. Much of the published information was the outcome of field and laboratory investigations aiming to assess the biology and population dynamics of *Artemia* in relation to biotope characteristics, targeting to *Artemia* mass production and its exploitation as feed for rearing of fish larvae, whereas only few of them were investigating the ecology of this organism.

As a result of a five-year investigation of brine reservoirs in the south of western Siberia (SibRybNII Proekt), a list of potential *Artemia* sites for the Siberian region was created in 1980s, and an expedition of the Institute of Zoology (NAS) of Belarus carried out a series of investigations on the biological characteristics of *Artemia* populations from different salt lakes of former USSR; these results have never or only partly been published (Baitchorov & Nagorskaya, 1999).

A few of the past studies, however, considered the taxonomical status of the species and the mode of reproduction (see Table 1). The taxon was often generically ascribed to *A. salina*, without any further investigation, or in some instances it was considered as *A. parthenogenetica* due to the unbalanced sex ratio recorded in the field. Often, contrasting information was also given for the same site by different authors on different occasions, thus arising confusion and doubts about the real situation (i.e Ku-

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TABLE 1. List of *Artemia* sites recorded in former USSR regions

| | Country/Lake | Coordinates | Region | Area ($km^2$) | Reproductive mode | References |
|---|---|---|---|---|---|---|
| | **Azerbadjan** | | | | | |
| 1 | pool near Sabuntchi | 40°30′N-49°57′E | Baku | | | 1, 13 |
| | **Ukraine** | | | | | |
| 2 | Adzhigol | 45°05′N-35°25′E | Feodosiya | | P | 2, 3 |
| 3 | Arabatskaya strelka | 45°40′N-35°00′E | Kirovskoye | | P | 2 |
| 4 | Dolgoye | 46°30′N-35°35′E | Azov | 0.5 | P | 4 |
| 5 | Dzharylhatch | 45°34′N-30°34′E | Tchernomorsk | 7.9 | P | 2, 5, 6 |
| 6 | Kizil-Yar | 45°03′N-33°55′E | Saki | 6.85 | B | 2, 7 |
| 7 | Kuialnik liman | 46°43′N-30°35′E | Odessa | 56 | P | 8, 9, 4, 10, 13 |
| 8 | Odzhigol | 46°25′N-32°13′E | Kherson | | | 11, 12, 13 |
| 9 | Otar-Moinakskoye | 45°12′N-33°30′E | Saki | 1.76 | P | 2, 5 |
| 10 | pools near Henhorka | 46°15′N-34°40′E | Henichesk | 0.04 | P | 31 |
| 11 | Popovskoye = Oyburgskoye | 45°17′N-33°05′E | Saki | 4.76 | P | 2, 34 |
| 12 | Sakskoye | 45°10′N-33°30′E | Saki | 4 | P | 6, 14, 2, 13 |
| 13 | salt ponds at W. Syvash | 46°15′N-34°40′E | Henichesk | | P | 15, 16, 4, 3 |
| 14 | Sasik-Sivash | 44°50′N-33°25′E | Saki | 71.8 | B, P | 3, 2, 7, 4, 13 |
| 15 | Shtormovoye | 45°20′N-53°05′E | Saki | | B | 34 |
| 16 | Sivash | 46°00′N-34°50′E | Kirovskoye | 2500 | P | 15, 16, 4, 3, 5,13 |
| 17 | Kinburgski peninsula | 46°25′N-31°40′E | Kherson | | | 11, 12, 13 |
| 18 | Sredneye | 46°30′N-35°30′E | Azov | 0.7 | P | 4 |
| 19 | Tchokrakskoye | 45°25′N-36°15′E | Kertch | 8.5 | B | 2, 34 |
| 20 | Tchongar | 46°00′N-34°35′E | Kirovskoye | | P | 3 |
| 21 | Tobetchikskoye | 45°10′N-36°20′E | Kertch | 9 | P | 2, 34 |
| | **Kazakhstan** | | | | | |
| 22 | B. Azhbulat | 53°15′N-77°30’E | Pavlodar | | | |
| 23 | Bolshoy Sarichaganack, Aral Sea | 46°30′N-61°15′E | Aralsk | | 17 | |
| 24 | Borli | 51°49′N-78°00′E | Pavlodar | 15.9 | P | 18, 34 |
| 25 | Horbatoye | 45°30′N-73°30′E | Balchash area | | P | 5 |
| 26 | Kalibek | 53°52′N-70°38′E | Koktchetav | 110 | | 19, 20 |
| 27 | Maraldi | 52°19′N-77°47′E | Pavlodar | 55 | P | 34 |
| 28 | Seyten | 51°56′N-78°07′E | Pavlodar | 15.5 | P | 34 |
| 29 | Severo-zapadnoye | 45°30′N-73°20′E | Balchash area | | P | 5 |
| 30 | Shoshkakol | 49°10′N-70°30′E | Karaghanda | 5.05 | | 19, 18, 20 |
| 31 | small pools near Schevtchenko | 43°35′N-51°03′E | Schevtchenko | | | 3 |
| 32 | Tastubeck, Aral Sea | 46°50′N-60°45′E | Aralsk | | | 17 |
| 33 | Teke | 53°50′N-72°56′E | Koktchetav | 265 | | 19, 18, 20 |
| 34 | Tenhiz | 50°25′N-69°00′E | Kustanai | | | 21, 8, 13 |
| 35 | Tuz | 51°19′N-78°39′E | Pavlodar | 2.81 | | 19, 13 |
| 36 | Yuzhnoye | 44°55′N-74°10′E | Balchash area | | P | 5 |
| | **Uzbekistan** | | | | | |
| 37 | Adzibay bucht, Aral Sea | 43°58′N-58°35′E | Moinack | | | 17 |
| 38 | Nazurok | 41°30′N-60°10′E | Khiva | | | 22 |
| 39 | pools near Sir-Darya | 40°50′N-68°30′E | Tashkient | | | 11 |
| 40 | pools of fishfarm, near Nuckus | 42°28′N-59°38′E | Karakalpakia | | | 23, 13 |
| 41 | Ulugshurkul | 41°20′N-60°30′E | Urhench | | | 22 |
| | **Kirghizstan** | | | | | |
| 42 | Aitaban | 41°05′N-72°28′E | Dzhalal-Abad | | | 8 |
| 43 | Kulat-Kul | 41°05′N-72°30′E | Dzhalal-Abad | | | 8 |
| | **Tadjikistan** | | | | | |
| 44 | Sasik-Kul | 37°35′N-73°10′E | Pamir | | | 24 |
| | **Russia** | | | | | |
| | **(W. Altay area)** | | | | | |
| 45 | Bolshoye Yarovoye | 52°50′N-79°45′E | Slavgorod | 66.7 | P | 25, 34, 13 |

(cont.)

| | | | | | | |
|---|---|---|---|---|---|---|
| 46 | Bolshoye Shklo | 52°35′N-79°15′E | Kulunda | 2.5 | P | 34 |
| 47 | Buazhonsor | 52°40′N-79°30′E | Blahoveschanski | 11 | P | 34 |
| 48 | Kulundinskoe | 52°55′N-79°40′E | Blahoveschanski | 728 | B, P | 25, 13, 34 |
| 49 | Kurichiye | 52°05′N-79°30′E | Klutchevskoye | 15 | P | 25, 34 |
| 50 | Kutchukskoye | 52°38′N-79°30′E | Blahoveschanski | 181 | P | 25, 13, 34 |
| 51 | Malinovoye | 51°55′N-79°50′E | Michailovsk | 11.4 | B | 26 |
| 52 | Maloye Yarovoye | 53°00′N-79°15′E | Slavgorod | 35.2 | P | 25, 34 |
| 53 | Mirabilit | 52°30′N-79°05′E | Kulunda | 1.9 | B | 34 |
| 54 | Mormishanskoye 1 | 52°30′N-81°20′E | Romanovo | 5.4 | P | 25, 34 |
| 55 | Mormishanskoye 2 | 52°25′N-81°15′E | Romanovo | 0.9 | P | 25, 34 |
| 56 | Petuchovo | 52°10′N-79°30′E | Klutchevskoye | 4.1 | P | 25 |
| 57 | Schekulduk | 52°27′N-79°00′E | Kulunda | 6.4 | P | 25, 34 |
| 58 | Solionoye | 52°45′N-81°50′E | Zaviyalovo | 1 | B | 25, 34 |
| 59 | Tanatar | 51°35′N-79°35′E | Michailovsk | 11 | B | 25, 34 |
| | **(Novosibirsk area)** | | | | | |
| 60 | Gorkoye | 54°10′N-77°30′E | Bahansk | 2.4 | | 27, 7 |
| 61 | Karatchi | 55°20′N-76°55′E | Tchani | 3.3 | P | 25 |
| 62 | Krutoberegovoye | 54°35′N-75°40′E | Tchistozerny | 1.2 | | 25 |
| 63 | Lechebnoye | 54°40′N-76°15′E | Tchistozerny | 2.2 | | 32 |
| 64 | Solionoye | 54°32′N-75°58′E | Tchistozerny | | | 32 |
| 65 | Solionoye | 54°20′N-76°45′E | Kupinsk | 0.1 | | 32 |
| 66 | Solionoye | 54°25′N-75°50′E | Tatarsk | 2.5 | | 32 |
| 67 | Tchani, (Udinski Ples) | 54°30′N-76°48′E | Tchistoozersk | 779 | | 13, 32 |
| 68 | Tuchloye | 54°34′N-75°12′E | Kupino | 17.3 | | 32 |
| 69 | Voniyucheye | 54°15′N-78°58′E | Krasnoozersk | 2.1 | | 32 |
| | **(Omsk area)** | | | | | |
| 70 | Ebeiti | 54°40′N-71°40′E | Poltavska | 83.2 | | 20, 25 |
| 71 | Ostrovnoye | 54°20′N-75°40′E | Tchistoozersk | 8.2 | | 25 |
| 72 | Ulzhai | 54°20′N-75°07′E | Cherlak | | | 25 |
| | **(Tiumen area)** | | | | | |
| 73 | Seledniyovo | 55°40′N-69°05′E | Berdiuzhye | 0.07 | P | 25 |
| 74 | Siverga | 55°30′N-68°40′E | Berdiuzhye | 53.6 | | 20, 25 |
| 75 | Solionoye | 55°20′N-70°00′E | Sladkovo | | | 25 |
| | **(Kurgan area)** | | | | | |
| 76 | Medvezheye | 55°18′N-67°55′E | Petuchovo | | | 25 |
| | **(Volgograd area)** | | | | | |
| 77 | Baskuntchack | 48°20′N-46°55′E | Volgograd | | | 15, 13 |
| 78 | Elton | 49°08′N-46°40′E | Volgograd | | | 15, 28, 8, 29, 13 |
| | **(Tcheliabinsk area)** | | | | | |
| 79 | pools near Troitsk | 54°05′N-61°35′E | Troitsk | | | 15, 13 |
| | **(Tchita area)** | | | | | |
| 80 | Bain-Tsahan | 50°15′N-115°02′E | Tchita | 0.4 | | 30 |
| 81 | Barun-Torey | 50°02′N-115°32′E | Tchita | 580 | | 30 |
| 82 | Zun-Torey | 50°03′N-115°45′E | Tchita | 300 | | 30 |
| | **(Vladivostok area)** | | | | | |
| 83 | tanks for salt fish in Kievka bucht | 43°50′N-133°40′E | Nakhodka | | | 7, 13 |
| | **(Khakasia)** | | | | | |
| 84 | Tus | 54°35′N-90°05′E | Abakan | 2.7 | | 33 |

P: parthenogenetic B: bisexual

List of references

1: Smirnov, 1933; 2: Voronov, 1976; 3: Rudneva, 1991; 4: Oleinikova, 1980; 5: Voronov, 1979; 6: Radchenko, 1982; 7: Lozovski, 1977; 8: Daday de Dées, 1910; 9: Decksbach, 1924; 10: Makarov, 1984; 11: Vekhov & Vekhova, 1992; 12: Vekhov & Vekhova, 1995; 13: Vekhov, 1993; 14: Ivanova & Svistunova, 1989; 15: Smirnov, 1940; 16: Voronov, 1975; 17: Aladin & Philipov, 1993; 18: Minsarinova *et al.*, 1991; 19: Struge & Lopatin, 1992; 20: Domanitski *et al*., 1971; 21: Sars, 1903; 22: Khakberdiev *et al.*, 1978; 23: Mnazhov, 1977; 24: Akhrorov & Oleinikova, 1976; 25: Solovov & Studenikina, 1992; 26: Yalinskaya & Strubitski, 1981; 27: Decksbach & Anferova, 1967; 28: Smirnov, 1948; 29: Behning & Medvedeva, 1926; 30: Lokot *et al.*, 1991; 31: Sevruck, personal communication; 32: Yermolayeva & Kipriyanova, personal communication; 33: Kosolapov & Kopylov, 2003; 34: Baitchorov & Nagorskaya, 1999.

ludinskoe population, bisexual according to Solovov & Studenikina, 1992 and parthenogenetic according to Baitchorov & Nagorskaya, 1999). Only at the end of 1990s, some authors started to publish in English, thus making information available to the scientific community.

Regarding distribution, on the basis of the existing literature references and of his own records, Vekhov (1993) has reported that the taxon he ascribes to the species *A. salina* inhabits the steppe, semi-desert and desert zones from the western coast of the Black Sea (southwestern Ukraine) to the eastern limits of the Kulunda Depression (Ob river, Russia), and is known also from the Far East (southern maritime province, Russia). Baitchorov & Nagorskaya (1999) have provided information about the reproductive characteristics of some *Artemia* populations from salt lakes in Crimea, Kazakhstan and Altay areas and mentioned both asexual and sexual taxa, without any further taxonomical detail.

A recent review about *Artemia* biogeography, based on literature data (Triantaphyllidis *et al*., 1998) available for Russia, Kazakhstan and Ukraine, added some information also on the mode of reproduction, although limited to a number of populations (29). According to this study most of the listed sites are inhabited by parthenogenetic populations (3 out of 4 listed in Kazakhstan; 12 out of 15 listed in Russia; 3 out of 10 listed in Ukraine), where the remaining ones are unidentified as bisexuals. Later on, Van Stappen (2002), also based on references and personal communications with a number of scientists, added another 14 populations to the list compiled by Triantaphyllidis *et al.* (1998) (1 for Ukraine; 5 for Kazakhstan; 5 for Russia; 3 for Uzbekistan), without providing any further information on species identification.

The aim of the present study is, on one hand, to review existing Russian literature on the subject and to compare information with recently published lists in order to enrich the present knowledge on *Artemia* distribution, and, on the other, to examine the morphological features of individuals from field collections preserved in the Institute of Zoology (NAS) of Belarus, in order to bridge existing gaps regarding the taxonomical position of these species, when possible, by using Scanning Electron Microscopy (SEM).

## MATERIALS AND METHODS

Literature references available since early 1900, were screened and organized in Table 1. A detailed analysis was performed on the material collected during the expedition of the Institute of Zoology (NAS) of Belarus, under the supervision of Dr. N. Khmeleva, which was carried out in the summer of 1988 to investigate *Artemia* biological characteristics from several lakes of former USSR (12 populations from Western Altay, 8 from Crimea and 3 from Kazakhstan).

All samples, collected in the past (23 populations, 37 samples) and stored in the collection of NAS, (kindly made available for this study), were re-examined for sex ratio and morphology of males.

Light and SEM microscopy preparations were made according to the methods cited in Wolfe (1980) and Mura (1991). Prior to SEM observation, samples were cleaned from formaline deposits by rinsing them thoroughly in tap water and by smooth sonication (if needed). For SEM observations, 20 to 30 individuals per sample were prepared and critical point dried in a Balzer 020 CPD Dryer. After mounting, the specimens were gold coated and examined with a LEO EVO 40 stereoscan. Two characters were considered: (i) frontal knob morphology and ornamentation (Mura *et al.*, 1989a,b), and (ii) shape and ornamentation of the non-retractile basal part of the penis (Triantaphyllidis *et al*., 1997; Mura & Brecciaroli, 2004).

When observing the specimens, care was taken to obtain identically oriented pieces in order to avoid possible image distortion. Males of the bisexual populations and rare parthenogenetic males were told apart based on sex ratio.

## RESULTS

The results of our literature screening are presented in Table 1. A total of 84 *Artemia* sites were listed (Fig. 1). Table 2 summarizes the results of our observations on the samples made available by Institute of Zoology (NAS) of Belarus. Out of 23 populations examined, 5 were represented by bisexuals, 3 consisted of mixed populations while the rest were assigned to the parthenogenetic group. Among the bisexual populations (Fig. 2), those from Altay area: Mirabilit (Fig. 3), Soliyonoe (Fig. 4) and Tanatar (Fig. 5), exhibited sub-spherical frontal knobs and spine-like projections on the basal penes. On the contrary, those from Ukraine (Kizil-Yar and Shtormovoye - Fig. 6) were characterized by sub-conical frontal knobs and lacked spine-like projections on the rigid part of penis.

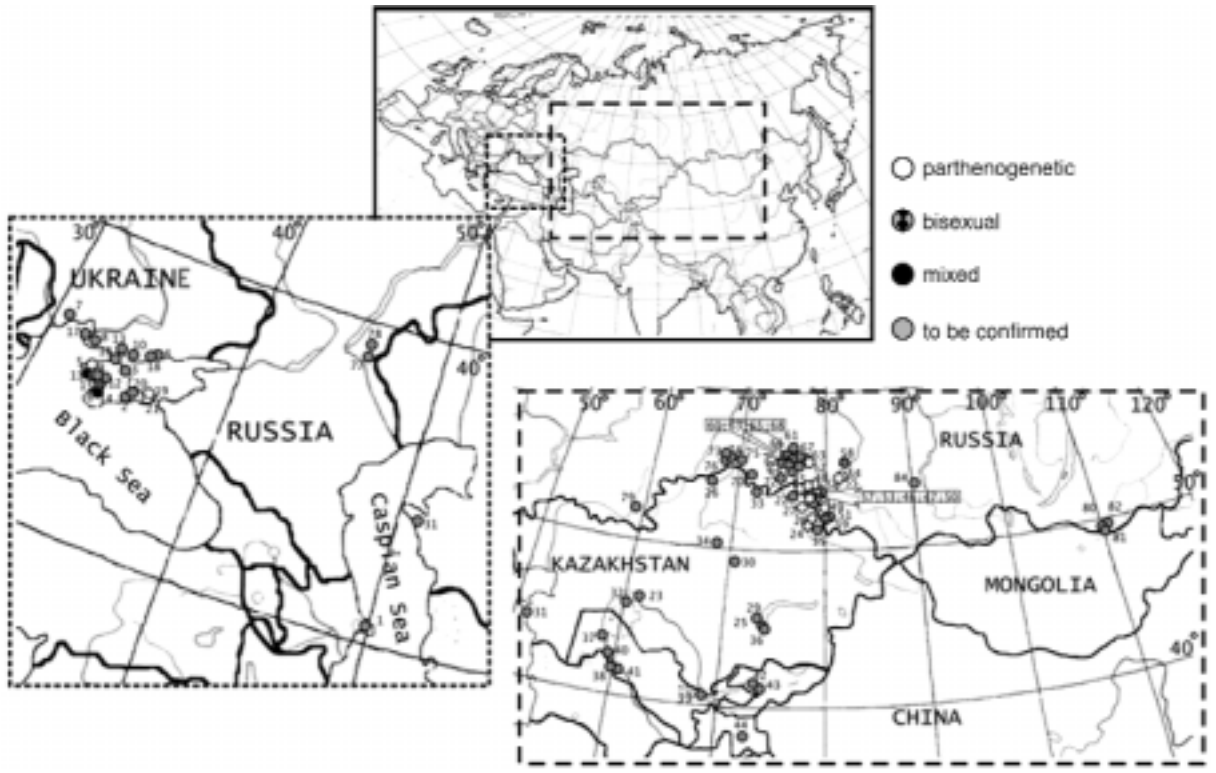


FIG. 1. Geographical location of the *Artemia* sites listed.

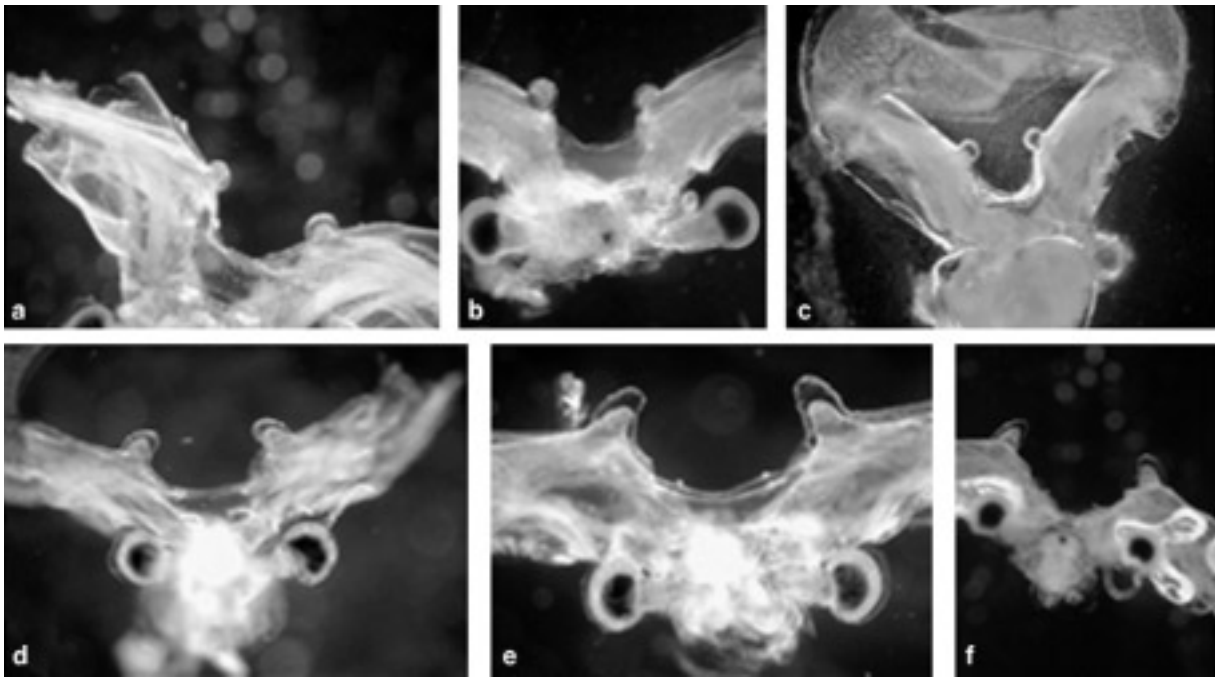


FIG. 2. Morphological differences (frontal knobs shape) recorded among the bisexual populations from various regions (light microscopy). a: Tanatar; b: Soliyonoe; c: Mirabilit; d: Shtormovoye; e: Kizil-Yar; f: Sasik-Sivash.

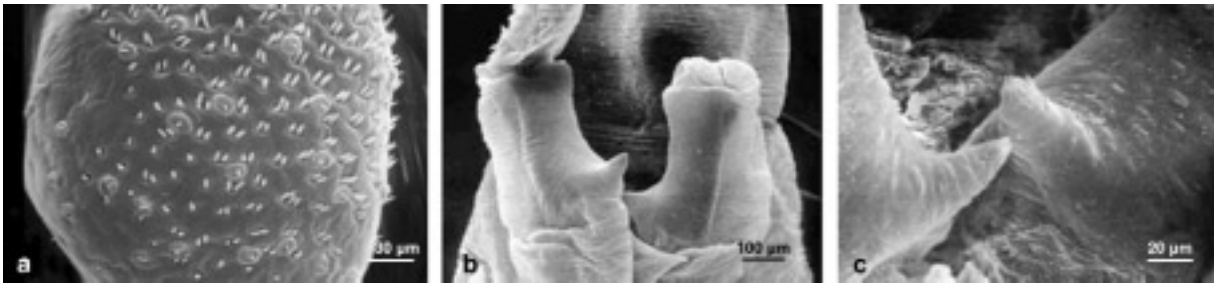


FIG. 3. SEM morphology of males from Mirabilit population. a: frontal knob surface; b: penes *in toto*, showing a spine-like projection on the basal part of penis; c: enlarged detail of spine ornamentation.

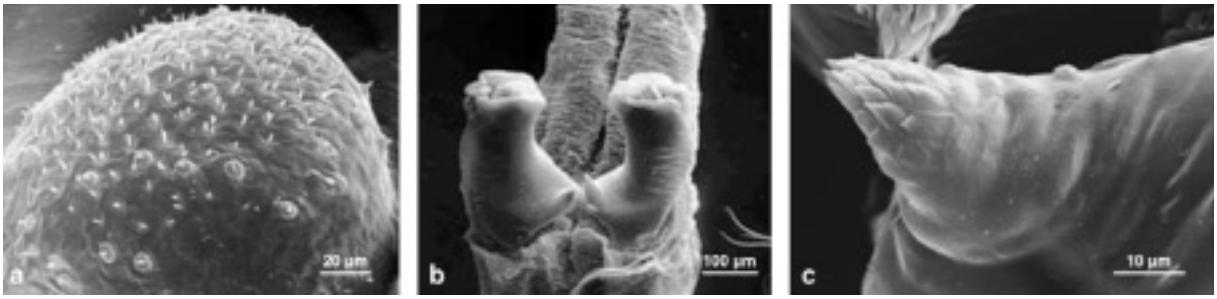


FIG. 4. SEM morphology of males from Soliyonoe population. a: frontal knob surface; b: penes *in toto*, a projection on the basal part of penis; c: enlarged detail of spine ornamentation.


FIG. 5. SEM morphology of males from Tanatar population. a: frontal knob surface; b: penes *in toto*, showing a spine-like projection on the basal part of penis; c: enlarged detail of spine ornamentation.

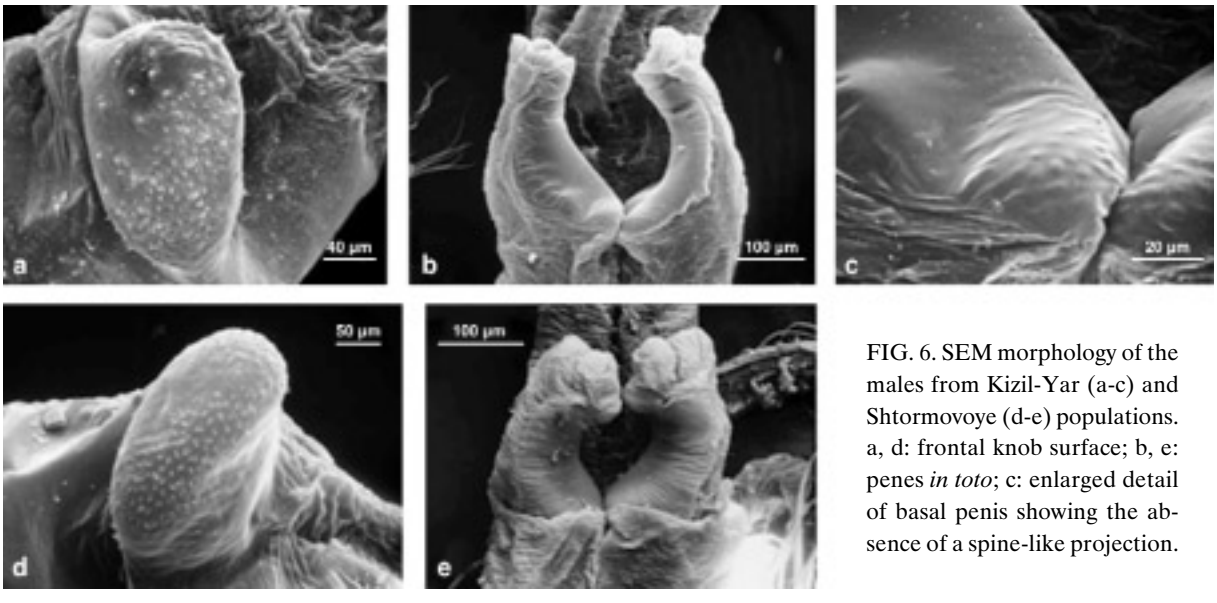


FIG. 6. SEM morphology of the males from Kizil-Yar (a-c) and Shtormovoye (d-e) populations. a, d: frontal knob surface; b, e: penes *in toto*; c: enlarged detail of basal penis showing the absence of a spine-like projection.

Interestingly, for Ukraine we also recorded mixed populations where both parthenogenetic and bisexual individuals were found (Table 2). This was the case for Popovskoye (= Oyburgskoye) (7 samples in June and July) (Fig. 7) population. The material collected in June was typically bisexual (ratio 1:1), whereas in July females were predominant with rarity of males. All of the rare males were characterized

TABLE 2. Morphological characteristics of the populations examined

| Area | Locality | Sample | Sex ratio | Rare males | Frontal knob shape | Spine on basal penis | Species |
|---|---|---|---|---|---|---|---|
| **Altay** | Bolshoye Yarovoye | 20/06/1988 | | no | | | parth |
| | | 29/06/1988 | 1/1000 | yes | sub-spherical | yes | parth |
| | Bolshoye Shklo | 20/07/1988 | | no | | | parth |
| | Buazhonsor | 15/07/1988 | 1/2000 | yes* | ? | ? | parth |
| | | 25/07/1988 | | no | | | parth |
| | Kuludinskoye** | 22/06/1988 | | no | | | parth |
| | | 15/07/1988 | 1/1000 | yes* | ? | ? | parth |
| | Kutchukskoye | 23/06/1988 | 1/2000 | yes | sub-spherical | yes | parth |
| | Kurichiye | 19/07/1988 | | no | | | parth |
| | Maloye Yarovoye | 13/07/1988 | 1/2000 | yes | sub-spherical | yes | parth |
| | | 25/07/1988 | 1/3000 | yes | sub-spherical | yes | parth |
| | Mirabilit | 27/06/1988 | 1/1 | | sub-spherical | yes | ? |
| | | 29/07/1988 | 1/1 | | sub-spherical | yes | ? |
| | Mormishanskoye | 15/06/1988 | | no | | | parth |
| | | 14/07/1988 | 1/1000 | yes | sub-spherical | yes | parth |
| | Schekulduk | 22/06/1988 | | no | | | parth |
| | Solionoye | 14/07/1988 | 1/1 | | sub-spherical | yes | ? |
| | Tanatar | 18/06/1988 | 1/1 | | sub-spherical | yes | ? |
| | | 28/06/1988 | 1/1 | | sub-spherical | yes | ? |
| **Ukraine** | Dzharylhatch | 30/06/1988 | 4/1000 | yes* | ? | ? | parth |
| | Kizil-Yar | 12/06/1988 | 1/1 | | sub-conical | no | *A. salina* |
| | | 15/07/1988 | 1/1 | | sub-conical | no | *A. salina* |
| | **Popovskoye**** | 16/06/1988 | 1/1000 | yes* | ? | ? | parth |
| | **(=Oyburgskoye**)** | 21/06/1988 | 1/2 | | sub-conical | no | *A. salina* |
| | | 30/06/1988 | 1/1000 | | sub-spherical | yes | parth. |
| | | 01/07/1988 | | no | | | parth |
| | | 06/07/1988 | 1/1 | | sub-conical | no | *A. salina* |
| | | 10/07/1988 | 1/1000 | yes | sub-spherical | yes | parth |
| | | 16/07/1988 | | no | | | parth |
| | **Sasik Sivash** | 15/07/1988 | 8/122 | | sub-conical | no | *A. salina* |
| | | 15/07/1988 | 1/122 | yes | spherical | yes | parth |
| | Shtormovoye | 20/06/1988 | 1/ 2 | | sub-conical | no | *A. salina* |
| | | 10/07/1988 | 1/2 | | sub-conical | no | *A. salina* |
| | Tchokrakskoye** | 10/06/1988 | 1/100 | yes | sub-spherical | yes | parth |
| | Tobetchikskoye | 11/06/1988 | 1/5000 | yes | sub-spherical | yes | parth |
| **Kazakhstan** | Borli | 16/07/1988 | | no | | | parth |
| | Maraldi | 01/07/1988 | | no | | | parth |
| | Seiten | 16/07/1988 | | no | | | parth |

* in bad condition
** contrasting with literature references
in bold mixed populations

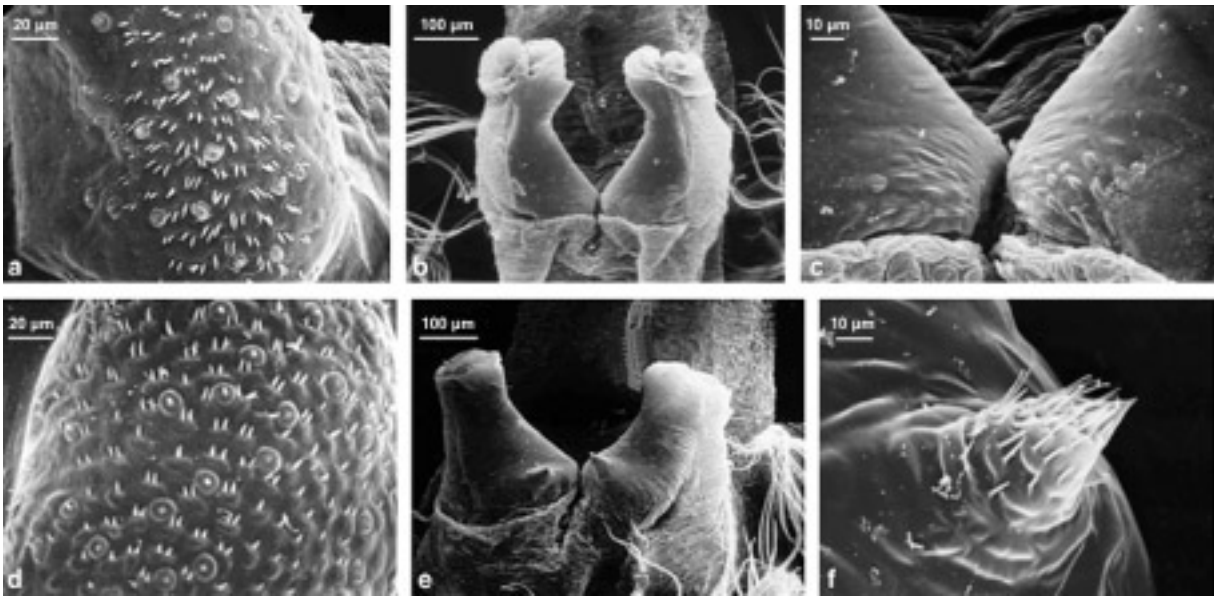


FIG. 7. SEM morphology of the bisexual (a-c) and rare (d-f) males from the mixed population of Popovskoye (=Oyburgskoye). a, d: frontal knob surface; b, e: penes *in toto*; c, f: enlarged detail of basal penis without spine in the bisexual (c) and with spine in the rare males (f).

by the presence of spine-like projections on the basal penis, whereas the bisexual ones did not.

A particular case was represented by the population from Sasik-Sivash (only one sample in July) having bisexual males (8 individuals) without spine-like projections and a presumably rare male with such projections on basal penis (Fig. 8).

Most of the parthenogenetic populations had a number of rare males, but few of them were in conditions good enough to obtain high quality pictures,

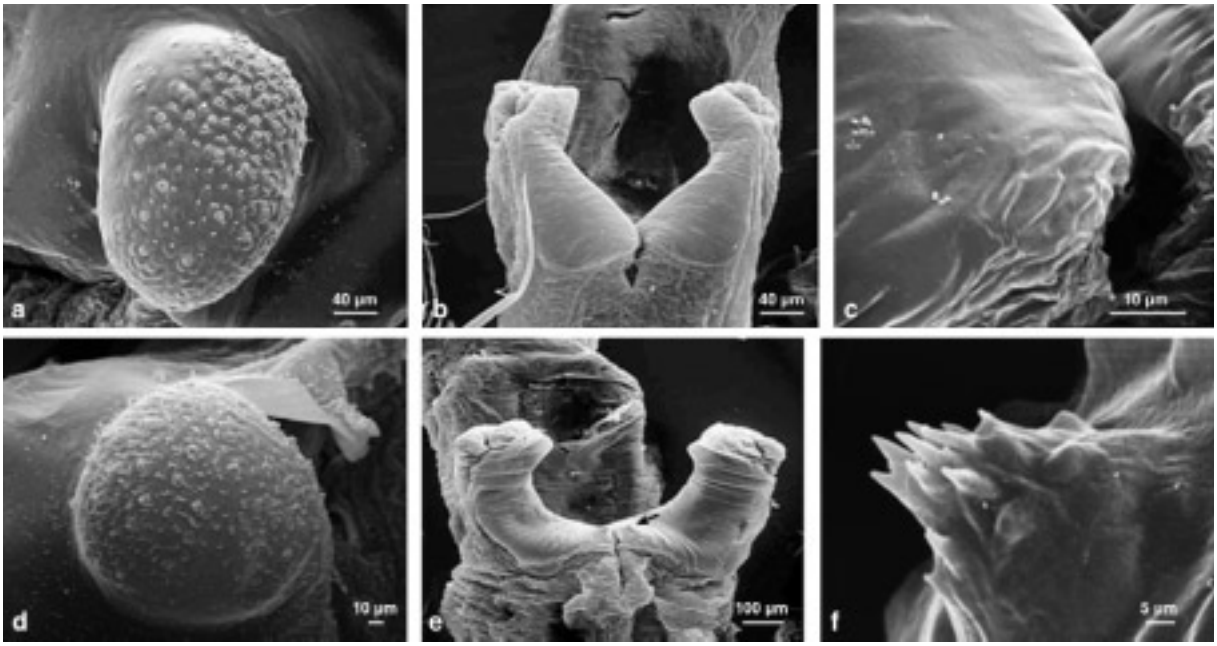


FIG. 8. SEM morphology of the bisexual (a-c) and rare (d-f) males from the mixed population of Sasik-Sivash. a, d: frontal knob surface; b, e: penes *in toto*; c, f: enlarged details of basal penis without spine in the bisexual (c) and with spine in the rare males (f).

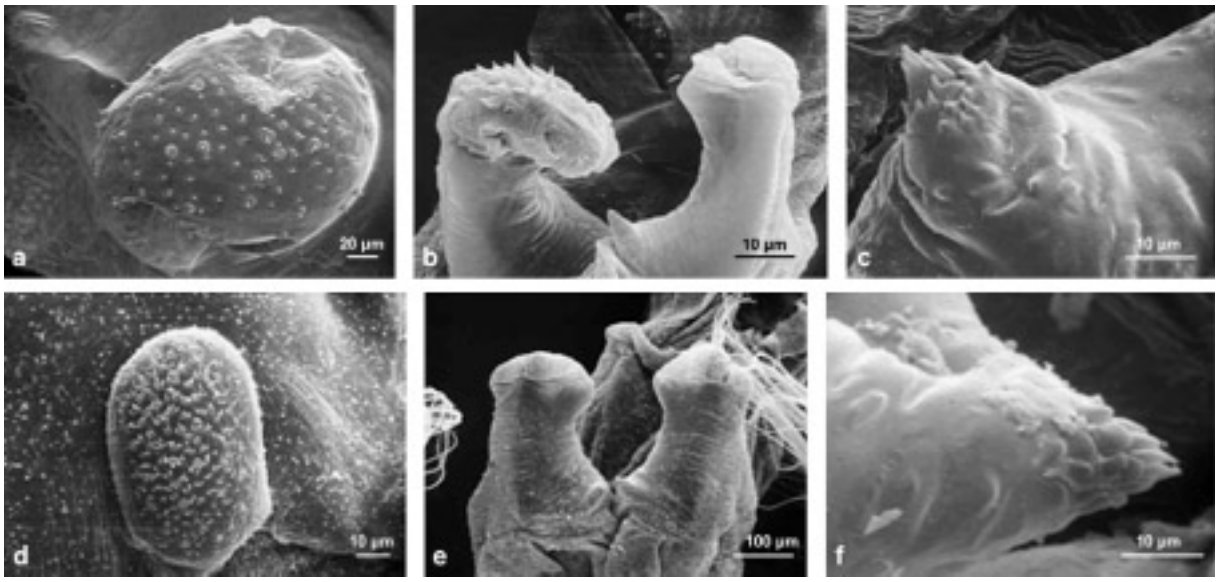


FIG. 9. SEM morphology of the rare males from Bolshoe Yarovoye (a-c) and Maloye Yarovoye (d-f) populations. a, d: frontal knob surface; b, e: penes *in toto*; c, f: enlarged details of the spine-like projections of the basal part of penes.

due to the age of the material and to poor preservation. However, rare males were all characterized by sub-spherical knobs and spine-like projections on basal penes (Figs 9 and 10), in line with previous unpublished observations on rare males from other areas (Mura, unpublished) (Fig. 11).

The ornamentation of the apical rosette of the spine-like projections was quite similar in the bisexual males examined (Figs 3-5), whereas a certain variation was evident in the rare males of the

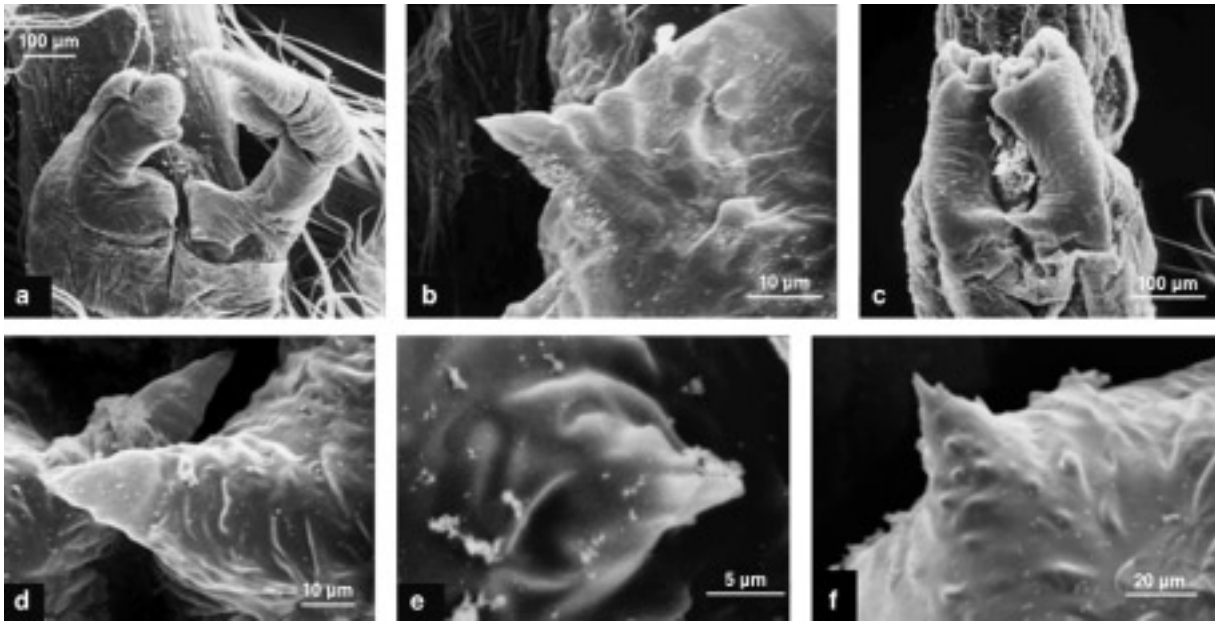


FIG. 10. SEM morphology of the rare males from Kutchukskoye (a-b), Mormishanskoye (c-d), Tobetchikskoye (e) and Tchokrakskoye (f) populations. a, c: penes *in toto*; b-f: enlarged details of the spine-like projections of the basal part of penes.

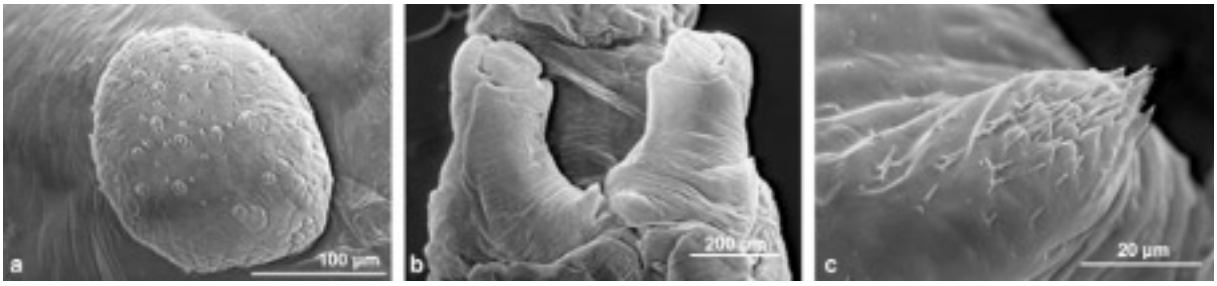


FIG. 11. SEM morphology of a rare male from Rocio (Spain) population. a: frontal knob appearance; b: penes *in toto*; c: enlarged detail of the spine-like projection on the basal part of penis.

parthenogenetic populations (Figs 9 and 10). Variation was also evident as for frontal knob ornamentation (number of spines and mechanoreceptors) among all of the populations examined, though it was not possible to evaluate it at individual level due to the poor condition of the sample.

## DISCUSSION

The comparison of the present results on sex-ratio with literature data, confirmed the available information for 23 populations analysed, with the exception of 3 cases: Kuludinskoe and Tchokrakskoye populations (bisexual according to part of the existing literature) (Table 1) were found to be parthenogenetic, and Popovskoe (= Oyburgskoye) population, previously considered parthenogenetic, but now found to be mixed population.

The analysis of few studies available on chromosome numbers, however, also outlined discrepancies as to our findings (Table 2), in that Tobetchikskoye (parthenogenetic population according to the determined sex ratio) and Kizil-Yar (bisexual according to this study) should comprise 2n, 1n and 4n individuals (Mitrofanov *et al*., 1976, 1982; Oleinikova, 1980).

A special concern refers to the *Artemia* population found in the artificial patch at the Posyet Bucht (the Far East) (tanks with salt store which were used for the fish salting). Probably the cysts were transported from different area of former USSR, including Crimea, where salt was extracted. Parthenogenetic cysts from these tanks show characteristics which were similar to those of the cysts from the Sasik (Crimea) and Karachi (Novosibirsk area) Lakes (Lozovski, 1977). The chromosome sets of *Artemia* from the Sasik Lake (4n for 51% metaphase plates) and those from the population in the salt tanks (chromosome numbers varied in the range 60-120) show different ploidy levels, in contrast to other Lakes investigated (Tobetchikskoye, Moinakskoye, Karatchi and Ontario Lakes where 2n = 42) (Mitrofanov *et al.*, 1982).

According to morphological observations, frontal knob morphology and ornamentation revealed consistent variation particularly in the ornamentation of knob surface that deserves further evaluation both at intraspecific and interspecific level on a proper number of freshly preserved individuals to extract useful information.

Based on the presence/absence of a spine on the basal part of penis, a character first used by Piccinelli & Prosdocimi (1968) to separate *A. salina* from the congener *A. persimilis,* and recently reconsidered (Triantaphyllidis *et al*., 1997; Mayer, 2002; Torrentera & Belk, 2002), we could add further information on the bisexual taxa, which are represented by *A. salina* in Ukraine and by a taxon yet to be defined in the rest of the territory.

As previously outlined by recent studies (Mura & Brecciaroli, 2004) in fact, all non-Mediterranean bisexual (both from New and Old World) exhibit spines on basal penes, having similar (except from *A. persimilis*), and highly variable ornamentation of the apical rosette (see Figs 8 and 9 in Mura & Brecciaroli, 2004), so that it is impossible to separate the species under study from the bisexual occurring in the rest of Asia (*A. sinica*, *A. urmiana*, *A. tibetiana*). The age of the samples did not permit preparing and using morphology of the retractile part of penis to obtain additional, probably helpful, information (Torrentera & Belk, 2002). According to these authors, in fact, the ornamentation of the retractile part of the penis differs at least in *A. franciscana* and *A. persimilis*.

The above considerations on one hand, stress the need for adequate funding in order to fill up the gap

still existing for former USSR territories concerning *Artemia* distribution and taxonomy, a matter of the greatest importance both from an ecological and a conservation point of view, in particular if we consider the danger represented by the invasive *A. franciscana* (Amat *et al*., 2005). On the other, we support the importance of careful multidisciplinary studies (both morphometrical and molecular) to solve taxonomical problems (Mura *et al*., 2005).

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