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RESEARCH ARTICLE

New records and redescription of the notostracan Tadpole shrimp, *Triops longicaudatus* (Le Conte, 1846) from temporary water bodies in North West region (Tabuk and Al-Madinah) of Saudi Arabia.

[1]Abdulhadi Bin Ahmed Aloufi and [2]Ahmad Hamed Obuid-Allah*

1. Zoology Department, Faculty of Science, Tabuk University, Saudi Arabia.
2. Zoology Department, Faculty of Science, Assiut University, Egypt.

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Corresponding Author

Ahmad H. Obuid-Allah

Abstract

The present study indicated that *Triops longicaudatus* (Le Conte, 1846) was recorded in 12 locations in North West region of Saudi Arabia. It includes its redescription from this region. The study revealed significant differences between females and males in some morphometric and meristic characters of the studied species.

Introduction

Notostracans are freshwater crustaceans adapted to temporary water bodies (Su and Mulla, 2001). They are recognized by their large, horseshoe-shaped dorsal carapace (Martin and Boyce, 2005). Longhurst (1955b) and Pennak (1978) indicated that the characteristic habitat of notostracans consists of muddy, alkaline pools which dry completely in the warm months. This type of intermittent habitat is usually found in arid or steppe regions. The tadpole shrimp is a name commonly given to many types of Triopsidae, including the genera *Triops* and *Lepidurus*. Since they are also present in the fossil record, there are a number of reports on their past and present distribution, as well as their morphology and reproduction (Longhurst 1955a,b; Hempel-Zawitkowska 1967; Igarashi 1970; Katayama 1973a,b ; Akita 1976 and others). There are about 15 species of tadpole shrimps and distribution is world-wide (except Antarctica) in fresh- and sometimes brackish temporary waters (Philip, 2012). The tadpole shrimp of genus *Triops* is a well known living fossil whose fundamental morphology has remained unchanged for 220 million years. While the order has wide geographical distribution, many species have a restricted local distribution (Suno-Uchi et al., 1997). Susan et al. (2005) indicated that removal of tadpole shrimp shortly after hatching reduced abundances of many taxa and decreased subsequent taxonomic richness and diversity. For many invertebrates, the presence of tadpole shrimp in low numbers had a positive effect on mean abundance. So, tadpole shrimp may be a key species controlling structure of macro invertebrate communities.

The present investigation is a part of a project which was mainly initiated to make an extensive survey on aquatic invertebrates including zooplankton inhabiting inland water of north-west region of Saudi-Arabia (Tabuk and Al-Madinah). During sampling the tadpole shrimp *Triops longicaudatus* was collected from different locations. This paper focuses on the distribution of the species as well as its description.

Materials and Methods:

Samples of tadpole shrimp were collected during day time by zooplankton net with a mesh size about100 µm during Winter-Spring months (From December 2013 till March 2014) and preserved in absolute ethanol in the field. Examination and measurements of samples were carried out under a binocular microscope equipped with a camera after transferring samples in tap water for several minutes to reduce shrinking of samples. During sampling, different physico-chemical parameters of the sites were taken using two probe electrodes. One probe measured pH/conductivity/total dissolved salts (TDS)/Salinity and temperature (Model: Multi-Parameter PCSTester tm 35-series. UOM: EA BOO4G8PWBO) and the other electrode measured dissolved oxygen (Model: DO600-ExStik II).

For preparing maps, remote sensing methods were used where the achieved images data of the maps were downloaded by Landsat 8 (2014) given by United States Geological Survey (USGS) (http://earth explorer. usgs.gov/). Also, The Environment visualizing images (ENVI) software virgin 5 was used for layer mosaics, stacking and image sub-sitting. Imported co-ordinates and map lay-out were prepared using ARCMAp10.1 software. SPSS software virgin 16 was used for analyzing data statistically.

Results:

Sites of collection (Figure 1).

The survey included118 locations; 76 locations covered Tabuk region and 42 locations covered Al-Madinah region. They could be classified into permanent lakes, temporary ponds, streams, wades, springs, wells and reservoirs. The species under investigation was recorded only at 12 sites. The physicochemical parameters were measured in the above-mentioned sites. The maximum depth at the investigated sites ranged between 0.5m- and 2.0m. The temperature of air ranged between 17°C and 37°C. Temperature of water ranged between 16°C and 27°C. Conductivity ranged between 145.8µS and 4460µS. The total dissolved salts ranged between 2.42e-7ppm and 3140 ppm. Dissolved oxygen ranged between 4.07 Mg/L and 10.99 Mg/L. The pH ranged between 8 and 10. The majority of sites were turbid.

Description of *Triops longicaudatus* (Le Conte, 1846) (Figures 2-4 and Tables 1-2)

Body dark green in the newly collected live specimens, widened anteriorly; length of the body including furca ranged between 1.9-6.5cm in females with an average length of 3.32cm while in males it ranged between 2.0-5.5cm with an average 3.25cm. No significant difference was detected between the length of females and males. The body segments varying from 35-39 segments in females with an average 36 segments while in males it ranged between 36-39 segments with an average of 37 segments. The T-test between the means of body segments revealed a highly significant difference between females and males. The number of abdominal segments bearing legs ranged between 12-18 segments in females with an average 14 segments. In males it ranged between 11-20 segments with an average 14 segments. The T-test between the means of the number of abdominal segments bearing legs revealed no significant difference between females and males. The number of abdominal legs ranged between 32-38 legs in females with an average 36 legs while in males it ranged between 23-36 legs with an average 30 legs. The T-test between females and males did not indicate significant difference in the number of abdominal segments.

The number of body legs ranged between 43-49 in females with an average 47 while in males it ranged between 34-47 with an average 41. The T-test gave a highly significant difference between females and males.

The apodous (legless abdominal segments): Each segment is provided posteriorly with a complete ring of spines directed posteriorly and ornamented with supernumerary spines especially in the ventral side. The number of apodous segments ranged in females between 10-12 with an average 11. In males it ranged between 11-14 with an average 13. The T-test between the means of apodous segments revealed a highly significant difference between females and males.

Carapace: Oval or rounded in shape and with distinct mandibular and cervical grooves. Its length ranged between 0.6-2.0cm in females with an average 0.99cm. In males it ranged between 0.6-1.8cm with an average 0.92cm. The width of the carapace ranged between 0.5-1.5cm in females with an average 0.92cm while in males it ranged between 0.6-1.7cm with an average 0.92cm. The T-test between the means of carapace length and width in females and males revealed no significant differences between females and males.

The posterodorsal surface of the carapace has scattered small denticles. Carina starts behind cervical groove and extends to the posterior margin of the carapace without terminal spines. The posterior margin of the carapace excavated and armed with spines. Maxillary gland elongated in shape. Compound eyes relatively large, paired in semicircular form, with their anterior parts close each others. Ocellus simple and small, situated on midline of carapace anterior to the compound eyes. The dorsal organ relatively large and triangular in shape.

Antennule: small, with two segments; the distal segment is longer than the proximal, weakly curved interiorly, with three sensory setae on its distal end, bearing small papillae on its distal two-thirds of outer margin. Antenna vestigial and reduced.

Mandible: Strongly bent terminally and without palp. Its distal triturating surface widened and bearing nearly three rows of distal denticulate teeth, some of these teeth are bicuspid.

The first maxilla: It is armed distally with setae and spines. The second maxilla absent.

The first leg: It consists of 5 endites, endopod, exopod and epipod. The first endite rounded and bears many denticulate marginal spines and setae.The remaining four endites are modified to flagellae and increasing in length distally. Each flagellum has a group of spinules at distal end and series of grouped spinules along lateral surfaces on both sides surrounding each segment. The second endite relatively short and bears different spines along its length. The third endite bears long and thin spines along its proximal part. Endopod relatively short and without any ornamentation. Exopod well developed and fringed with plumose setae on outer margin and with dense spinules on the inner margin.

Second leg: With four, relatively short, endites nearly equal in size. The endopod larger with spinules and plumose setae.

The legs except the first two and eleventh leg among all legs are similar in shape but decreasing in size toward posterior region, having diverse ornamentations. **The 10^{th} leg:** the first endite rounded, looks like that of the 1^{st} or 2^{nd} leg in ornamentation. The remaining four endites are leaf- shaped, armed with spinose setae. Large scattered spines, groups of short and thin setae, and fine situles are found along the rounded margins. Also, two transverse rows, one of long spinose setae and the other with short spines, on anterior middle surface of each endite.

Eleventh leg: It resembles the 10^{th} leg, but in the female; the two exopodites form egg-sac containing eggs in mature female.

Telson: Without supra-anal plate and provided dorsally with four groups of spines. The 1^{st} group is a median one, consists of a row of about 6 spines. The 2^{nd} group is a distal one that includes two latero-distal spines. The third group is situated dorso-laterally including a cluster of about 5 spines. The 4^{th} group is the lateral one which includes numerous spines scattered laterally and increasing in size terminally. The ventral side of the telson has scattered spines which increase in size terminally. The length of telson ranged between 0.1-0.2cm in females with an average length 0.12cm. In males it ranged between 0.1-0.2cm with an average length 0.11cm. Its width ranged between 0.1-0.3cm in females with an average width 0.16cm in females while it ranged between 0.1-0.25cm in males with an average width 0.16cm. The T-test between the means of telson length and width in females and males revealed no significant differences between females and males.

Furca: Relatively long and thin with numerous segments, each segment armed with a ring of nearly equal sized spinules. The furcal rami length ranged between 0.7-2.8cm in females with an average length 1.36cm while in males it ranged between 0.8-1.6cm with an average 1.12cm.

Table (1): Illustrates some morphometric (in cm) and meristic characters of *Triops longicaudatus*.

The character	Females (n= 13)			Males (n=11)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Body length	1.9	6.5	3.32	2.0	5.5	3.25
Carapace length	0.6	2	0.99	0.6	1.8	0.92
Carapace width	0.5	1.5	0.92	0.6	1.7	0.92
Telson length	0.1	0.2	0.12	0.1	0.2	0.11
Telson width	0.1	0.3	0.16	0.1	0.25	0.16
Furcal rami length	0.7	2.8	1.36	0.8	1.6	1.12
Number of body segments	35	39	36	36	39	37
Number of abdominal segments bearing legs	12	18	14	11	20	14
Number of legless abdominal segments (apodous)	10	12	11	11	14	13
Number of abdominal legs	32	38	36	23	36	30
Number of body legs	43	49	47	34	47	41

Table (2): Illustrates the results of T-test between the means of different body measurements of males and females of *Triops longicaudatus.*

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Body length	0.263636	1.662692	0.501321	0.525884	10	0.610
Carapace length	0.136364	0.564398	0.170172	0.801326	10	0.442
Carapace width	0.054545	0.450252	0.135756	0.40179	10	0.696
Telson length	0.018182	0.060302	0.018182	1	10	0.341
Telson width	0.011818	0.069544	0.020968	0.563621	10	0.585
Furcal rami length	0.309091	0.648775	0.195613	1.580114	10	0.145
Number of body segments	-1.45455	1.507557	0.454545	-3.2	10	*0.009
Number of abdominal segments bearing legs	0.818182	2.63887	0.795649	1.02832	10	0.328
Number of legless abdominal segments (apodous)	-2.72727	1.190874	0.359062	-7.59555	10	*0.00
Number of body legs	5.27273	5.40538	1.62978	3.235	10	*0.009

* < 0.05: Significantly different.

Table (3): Illustrates some morphometric and meristic characters of *Triops longicaudatus* investigated in the present study compared with the same species studied by other authors.

The character	Present study	Yoon et al. (1992)	Longhurst (1955a)
Body length	* 1.9-6.5 cm (females) 2-5.5 cm (males)	** 0.56-2.68 mm (females)	-
Carapace length	0.6-2.0 cm (females) 0.6-1.8 cm (males)	0.36-1.59 mm (females)	15-30 mm for all usual Triops species. 40 mm in giant specimens.
Carapace width	0.5-1.5 cm (females) 0.6-1.7 cm (males)	0.43 – 1.68 mm	-
Number of body segments	35-39 (females) 36-39 (males)	36-37 (females)	35-43 (females) 35-44 (males)
Number of abdominal segments bearing legs	12-18 (females) 11-20 (males)	17-19 (females)	-
Number of legless abdominal segments (apodous)	10-12 (females) 11-14 (males)	7-8 (females)	5-12 (females) 10-13 (males)
Number of body legs	43-49 (females) 34-47 (males)	58-63 (females)	54-66

* The length including furca.
** The length excluding furca.

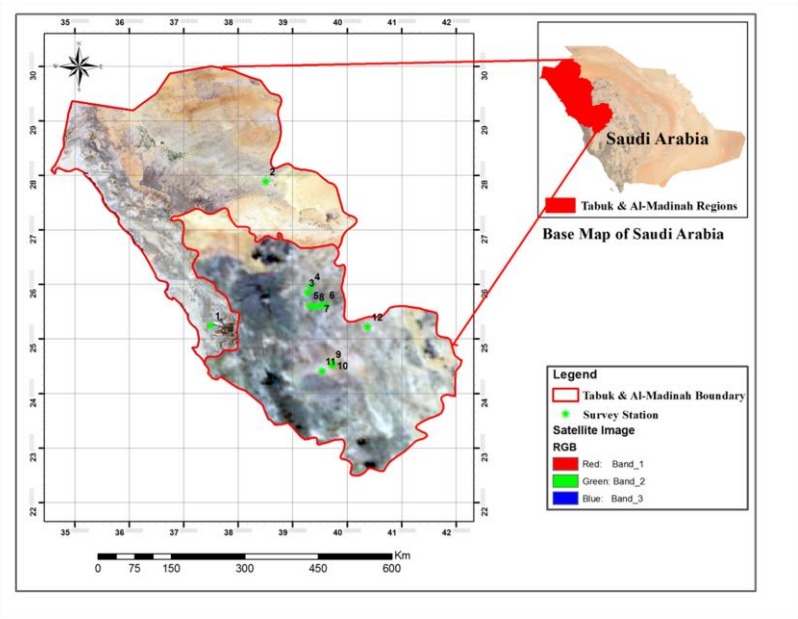

Fig. (1) A map showing the distribution of *Triops longicaudatus* at the investigated north west region of Saudi Arabia.

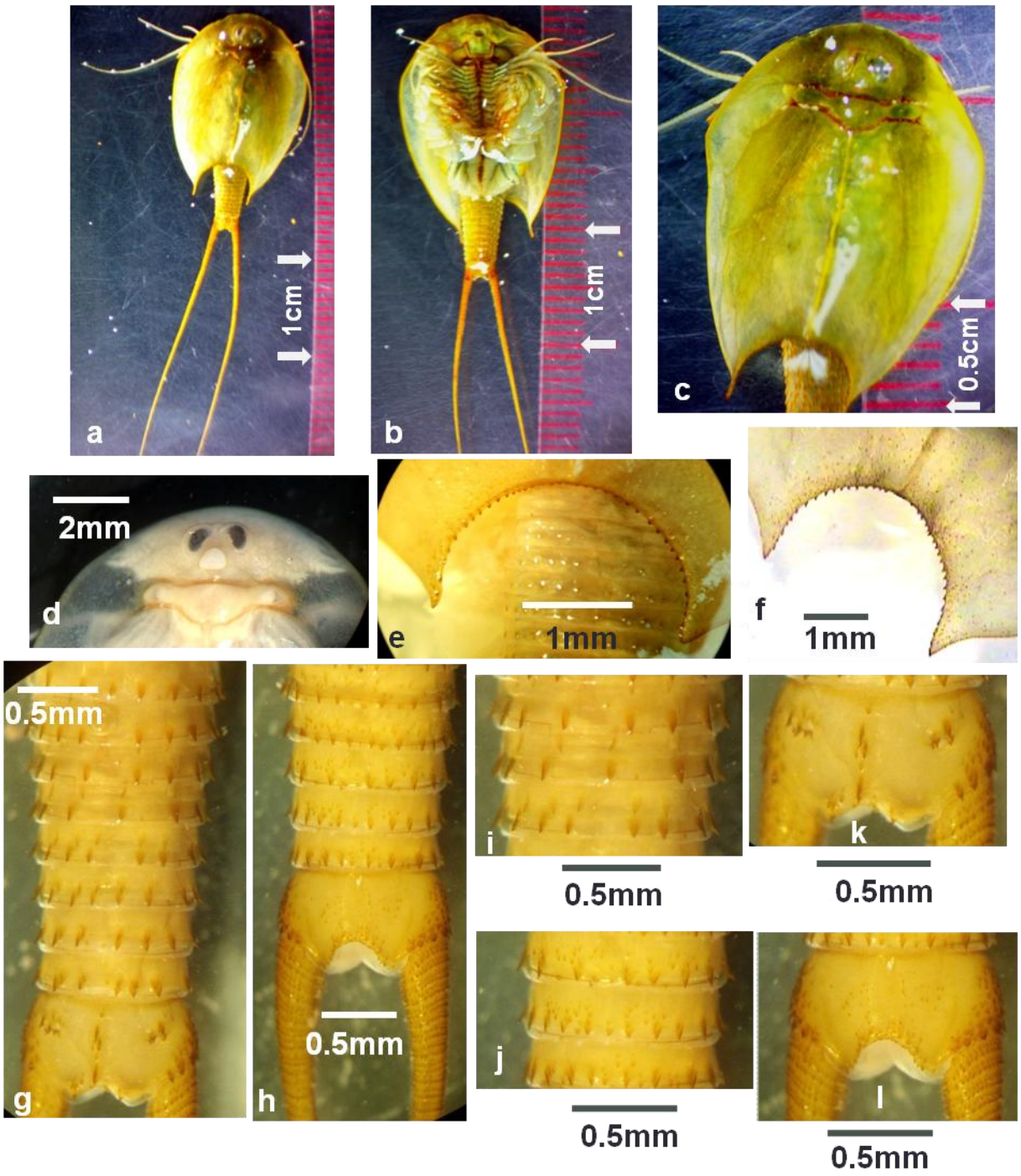

Fig: (2) *Triops longicaudatus*, a: dorsal view (female), b: ventral view (female), c: enlarged anterior part of the body (dorsal view), d: enlarged eyes and dorsal organ, e: enlarged sulcus (dorsal view), f: enlarged sulcus (ventral view). g: dorsal view of the distal part of the abdomen of a female , h: ventral view of the distal part of the abdomen of a female. i: some enlarged segments of the abdomen of the female (dorsal view), j: some enlarged segments of the abdomen of the female (ventral view), K: telson of a female (dorsal view). l: telson of a female (ventral view).

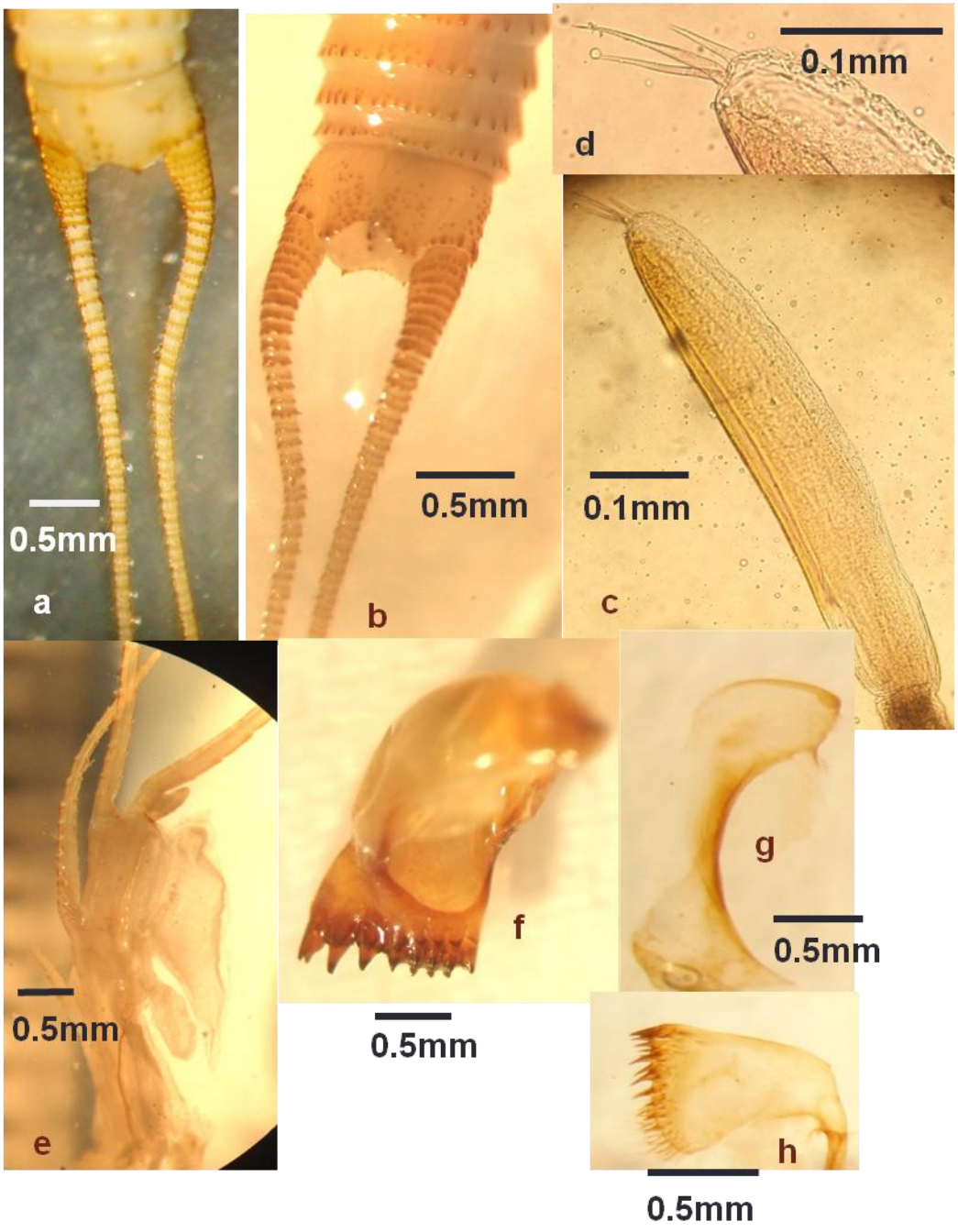

Fig: (3) *Triops longicaudatus*, a: distal part of the abdomen showing telson and furca of a male (dorsal view), b: distal part of the abdomen showing telson and furca of a male (ventral view), c: left antennule, d: enlarged distal portion o the antennule, e: left first leg (posterior face), f: left mandible, g: paragnath, h: first maxilla.

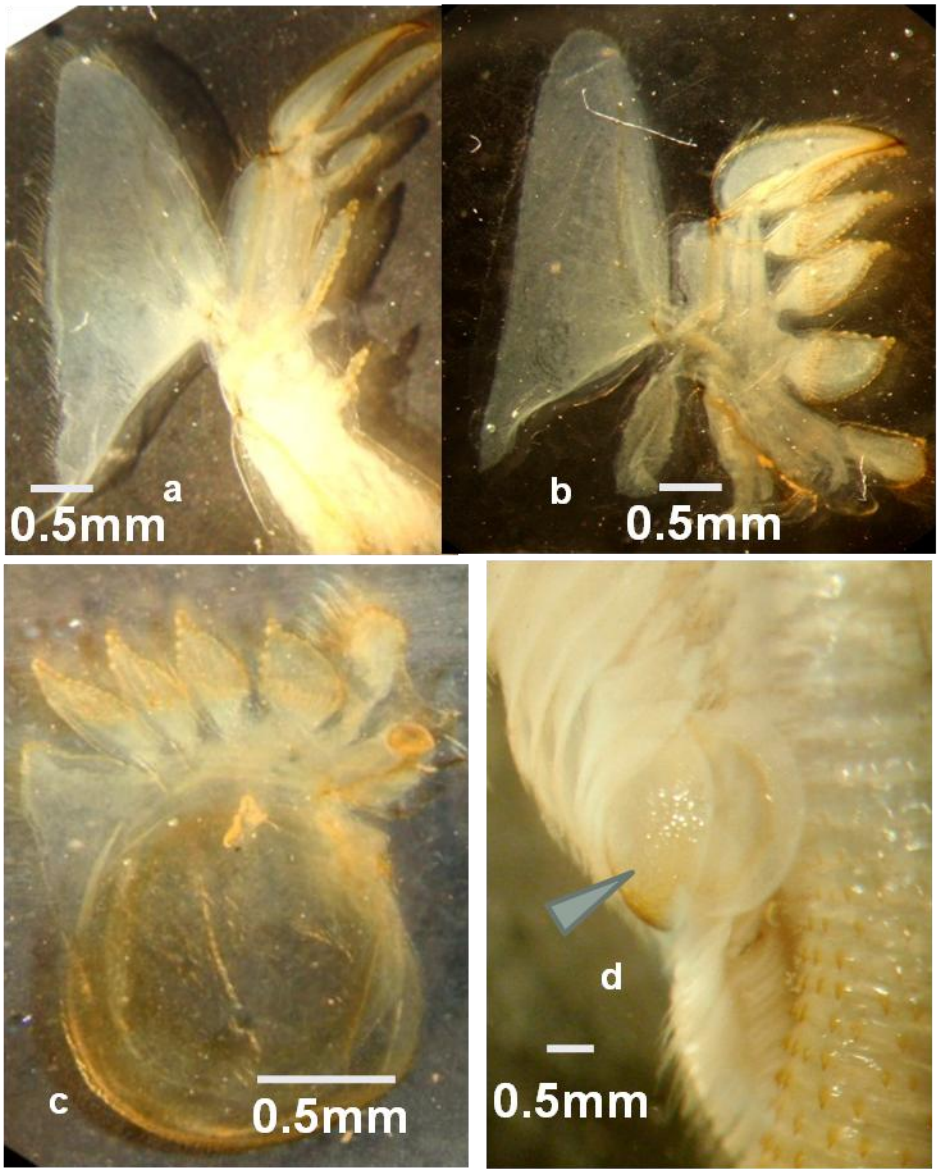

Fig: (4) *Triops longicaudatus*; a: left second leg (anterior face), b: left tenth leg, c: left eleventh leg of a female, d: enlarged part of thorax and abdomen of a female showing eleventh leg (ventral view).

Discussion:

Longhurst (1955a) in his review of Notostraca indicated that most species appear to have great variations in their morphology and a lot of confusion in identifying the species exists. He considered three characters as taxonomically important ones; the armature of the telson, the presence or absence of the second maxilla and the arrangement of the eyes and the dorsal organ as important ones in this group. Relying on the above mentioned characters and compared with previous studies like that of Yoon et al. (1992), the species under investigation proved to be *Triops longicaudatus*. *Triops longicaudatus* is distinguished from *Triops cancriformis* (Bosch, 1801) and *T. granarius* (Lucas, 1864) by the absence of the second maxilla, and *T. australiensis* (Spencer and Hall, 1896) by the armature of the telson, especially the arrangement of the median spines. Alain (1996), in his taxonomic and faunistic account of the large branchiopods of the Arabian Peninsula, identified three notostracan species: *Triops numedicus*

in the central area of the Peninsula while he recorded *Triops cancriformis simplex* in northern Yemen and genus *Lepidurus* in Syria. The above author indicated that *Triops numedicus* has been known from Arabia for many years (Longhurst 1955a, 1958). It has been named *Triops granarius* in almost all publications, but Brtek and Thiery (1995) argued that it was, in fact, a synonym of *T. numidicus* described by Grube (1865). While the species *Triops numedicus* is well known (see Longhurst 1955a, Rayner and Bowland 1985, Thiery 1987, Seaman et al. 1991, Meintjes et al. 1994), its variability is always discussed, particularly in the number of body rings and apodous rings. Alain (1996) indicated that for all the Saudi Arabian samples, the number of apodous segments (excluding telson) is: Females: 9-12, Males: 14-15; total number of segments: Females: 36-39, Males: 38-39. He indicated that the nucal organ is rounded and quadrangular with a horizontal base, telson with numerous spines and telson of the male covered with numerous acute scales. The abovementioned measurements for *T. numidicus* by Alain (1996) are nearly within the ranges measured in the present study for *T. longicaudatus* but it differs than *T. numidicus* in the absence of the second maxilliped and the rectangular shape of the dorsal organ. A recent study by Montaser et al. (2014) on the community structure of zoobenthos in some freshwater bodies in Taif, Saudi Arabia recorded *Triops longicaudatus* among the collected taxa.

The present study recorded some significant differences between females and males of *T. longicaudatus*. These differences included number of body segments, number of apodous segments and number of body legs. This result is in accordance with that noticed by Longhurst (1955a) where he mentioned that certain characters are correlated with the sex of the specimen; males tend to have more segments than females and that apodous segments vary between males and females. He added that the ventral armature of the furca of males is coarse, often forming scales rather than spines. This character was noticed in the present studied species.

Comparing some morphometric and meristic measurements of the studied species with the same species studied by Yoon et al. (1992) from Korea and Longhurst (1955a) (Table: 3). It could be concluded that some of these characters within the range recorded by Longhurst (1955a) like the number of body segments, number of apodous segments and number of body legs. In contrast, the ranges recorded in the present study are mostly outside those recorded by Yoon et al. (1992). These differences may be attributed to habitat, sex or the number of the specimens examined. Yoon et al. (1992) in their study based their description of the species on young females only since they did not collect males.

Longhurst (1955a) and Katayama (1973a) mentioned the distribution of *Triops longicaudatus* as North America (south of 50°N), central-south America, West Indies, Galapagos islands, Hawaii, New Caledonia, and Japan. The wide spread species of Notostraca is due to their passive distribution; the dried viable eggs must be blown around by wind, and transported by birds for the eggs when laid are extremely sticky and remain so for some days while the shell hardens, and so could presumably adhere to large animals (Longhurst, 1955a). The eggs of other phyllopods are known to be capable of passing unharmed through the guts of amphibian (Mathias, 1937), and birds are known to eat Notostraca; starlings (Decksbach, 1924) and gulls (Balfour-Browne, 1909) were recorded as feeding on *Triops canriformis* and Summerhayes and Elton (1923) watched Arctic terns feeding *Lepidurus arcticus* to their young, and thought that they might drop them accidentally into fresh pools on their way to the nest. Longhurst (1955a) indicated that a passive distribution such as this must mean that geographical barriers are not nearly so effective as they are for sedentary, or non-passively distributed animals, and has produced species with world-distribution in other animals, such as Tardigrades and Rotifera. In addition, the group has a very long geological record and has had ample time to occupy all suitable areas. Adams et al. (2014) indicated that *Triops cancriformis* was able to disperse between discrete habitat patches over distances of at least several kilometers and successfully colonize new sites and that the mechanisms of this dispersal are unknown but transfer of material during floods or on the feet of deer, livestock, humans, waterfowl, or on farm machinery are all highly possible. Christopher et al. (1978) indicated that flood possibly plays an important role in dispersion of *Triops longicaudatus*.

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References:

Adams, C.E; Griffin, L.R; Benzies, E; Aherne, D., Bean, C.W., Dodd, J.; Fairlamp, D.; and Maitland, P. S. (2014): Short range dispersal by a rare, obligate freshwater crustacean *Triops cancriformis* (Bosc). Aquatic Consev: Mar. Freshw. Ecosyst. 24: 48-55.

Akita, M. (1976): Classification of Japanese tadpole shrimps. Zoological Magazine 85: 237-247.

Alain, T. (1996): Large branchiopod (Crustacea: Anostraca, Notostraca, Spinicaudata, Laevicaudata) from temporary inland waters of the Arabian Peninsula. Fauna of Saudi Arabia 15: 1996; 37-98.
Balfour-Browne, F. (1909): Notes on the rediscovery of *Apus cancriformis* in Britain. Ann. Scot. Nat. Hist. 1909. 118.
Brtek, J and Thiery, A. (1995): The geographic distribution of the European Branchiopods (Anostraca, Notostraca, Spinicaudata, Laevicaudata). Hydrobiologia 298: 263-280.
Christopher, M. T.; Richard, M. B. J.and Richard, E. H. (1978): Eastward range extension of the tadpole shrimp, *Triops longicaudatus* (Leconte), in Oklahoma. Proc. Okla. Acad. Sci. 67: 75-76 (1987).
Decksbach, N. K. (1924): Zur Verbreitung und Biologie der Apusidae in Russland. Russ. Hydrobiol. Zeits. 3: 143-155.
Hempel-Zawitkowska, J. (1967): Natural history of *Triops cancriformis* (Bosc.). Zoologica Poloniae 17: 173-239.
Igarashi, K. (1970): Ecological studies of *Triops longicaudatus* (Notostraca) inhabiting Shonai district, Japan. 2. Journal of Yamagata Agriculture and Forestry Society 27: 34-39. (In Japanese with English summary).
Katayama, H. (1973a): The species of *Triops* and their distribution in Osaka district. Nature Study 19: 62-67. (In Japanese).
Katayama, H. (1973b): Biological control of weeds by tadpole shrimps in paddy fields1, 2. Nogyogijutu (Journal of Agricultural Technology) 28: 161-163, 208-213. (In Japanese).
Longhurst, A. R. (1955a): A review of the Notostraca. Bull. Brit. Mus. (Nat. Hist.) Zool. 3:1-57 (1955).
Longhurst, A. R. (1955b): Evolution 9: 84-86 (1955).
Longhurst, A. R. (1958): Abnormal variation in Notostraca. Systematic Zoology 7 (2): 84-88.
Martin, J. W. and Boyce, S. L. (2005): Crustacea: Non cladoceran Branchiopoda, pp. 284-297.
Mathias, P. (1937): Biologie des Crustacees phyllopodes. Paris, 1937.
Meintjes, S.; Seaman, M. T. and Kok, D. J. (1994): Variations in the morphological characteristics of *Triops granarius* (Lucas) (Crustacea: Notostraca) in a pan system at Bain's Vlei, South Africa. Hydrobiologia 277: 179-186.
Montaser, M. H.; Hamada, M. M., and Khaleid F. A. (2014): Community structure of zoobenthos in some freshwater bodies in Taif, Saudi Arabia. International Journal of Advanced Research (2014), Volume 2, Issue 4, 114-127.
Pennak, R. W. (1978): Freshwater invertebrates of the United States, John Wiley and Sons, New York, NY, 1978, pp. 326-346.
Philip, M. G. (2012): An introduction to the branchiopod crustaceans. Quekett J. of Microscopy, 2012, 41, 679-694.
Rayner, N. A. and Bowland, A. E. (1985): Notes on the taxonomy and ecology of *Triops granaries* (Lucas) (Notostraca) (Crustacea) in South Africa. South African Journal of Science 81: 500-505.
Seaman, M. T.; Kok, D. J.; Schlichting, B. J. and Kruger, A. J. (1991): Natural growth and reproduction in *Triops granarius* (Lucas) (Crustacea: Notostraca). Hydrobiologia, 212: 87-94.
Su, T. and Mulla, M. S. (2001): Effects of nutritional factors and soil addition on growth longevity and fecundity of the tadpole shrimp *Triops newberryi* (Notostraca: Triopsidae), a potential biological control agent of immature mosquitoes. J. Vector Ecol, 26 (1): 43-50.
Summerhayes, V. S. and Elton, C. S. (1923): Contribution to the ecology of Spitzbergen and Bear Island. J. Ecol. 11: 214.
Suno-Uchi, N.; Sasaki, F.; Chiba, S. and Kawata, M. (1997): Morphological stasis and phylogenetic relationships in tadpole shrimps, *Triops* (Crustacea: Notostraca). Biochemi J. Linnean Soc., 61 (4): 439-457.
Susan, H. Y.; Michael, R. W. and Daryl, L. M. (2005): Tadpole shrimp structure macro invertebrate communities in playa lake microcosms. Hydrobiologia (2005) 541: 139-148.
Thiery, A. (1987): Les Crustces Branchiopodes, Anostraca, Notostraca et Conchostraca des milieux Limniques temporaires (Dayas) au Maroc. Taxonomie, Biogeographie, Ecologie. 405 pp. These Doctorat d'Etat es Sciences, Universite Aix-Marseille III.
Yoon, S. M.; Kim, W. and Kim, H. S. (1992): Redescription of *Triops longicaudatus* (LeConte, 1846) (Notostraca, Triopsidae) from Korea. The Korean Journal of Systematic Zoology. Special Issue No. 3: 59-66. (October 30, 1992).