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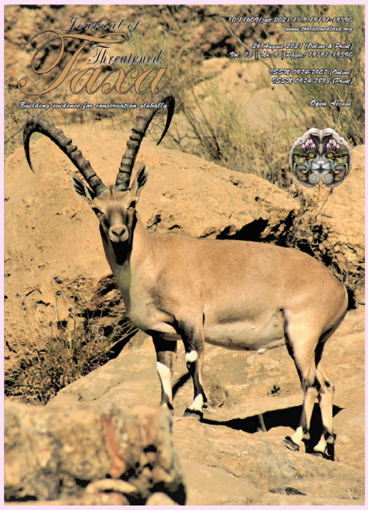

COMMUNICATION

FIRST REPORT OF THREE SPECIES OF THE GENUS *DIAPHANOSOMA* (CRUSTACEA: CLADOCERA: SIDIDAE) FROM JAMMU WATERS (J&K), INDIA

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COMMUNICATION

First report of three species of the genus *Diaphanosoma* (Crustacea: Cladocera: Sididae) from Jammu waters (J&K), India

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Abstract: Cladocera, commonly known as 'water flea' due to the jerky movements produced by their second antennae, form an important food component for planktivorous fishes and other aquatic invertebrates. The present investigation comprising a collection of zooplankton samples from a shallow pond located in the Bishnah tehsil of Jammu district has revealed the presence of 13 Cladocera species belonging to the families Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae. Three species of the family Sididae belonging to the genus *Diaphanosoma*, namely, *senegal, sarsi* and *excisum* are new species records to the cladoceran fauna of Jammu & Kashmir. Presently, a detailed morphological analysis has been made on all the three *Diaphanosoma* species. They have shown major differences in their body size with *D. senegal* being larger than *D. sarsi* and *D. excisum*. All three species have well observable variability with reference to their head size, eye size, shell duplicature, shape of posterior valve margin, and the number of denticles so present on posterior valve margin. All the three species have also shown coexistence with each other, but *D. senegal* was dominant in terms of population density.

Keywords: *Diaphanosoma excisum, D. sarsi, D. senegal,* invertebrates, Jammu & Kashmir, morphology, variability.

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Author details: Nidhi Sharma is a UGC research fellow, pursuing Ph.D. under the supervision of Dr. Sarbjeet Kour in the department of Zoology, University of Jammu. She is working on taxonomy, diversity assessment, population structure and ecology of freshwater zooplankton. Dr. Sarbjeet Kour is currently working as Assistant Professor in the department of Zoology, University of Jammu. She has a research experience of 20 years in the field of limnology and aquatic biology. Her area of specialization includes freshwater ecology, water quality analysis, biodiversity and zooplankton ecology.

Author contributions: NS—carried out the fieldwork, sampling, species identification, data collection, analysis & interpretation and manuscript writing. SK—supervision and guidance in sample collection, careful examination and confirmation of identified species, thorough checking, input of intellectual content and final approval to the manuscript.

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ज्ञान - विज्ञानं विमुक्तये

INTRODUCTION

Zooplankton being an important component of aquatic biota, play an essential role in influencing all the functional aspects of an aquatic ecosystem like food web, food chain by occupying the position at primary consumer level and acting as the trophic link between bottom-up factors (primary producers) and top down regulators (higher trophic levels) (Murugan et al. 1998). They are of considerable value as bioindicators and aid in determining the trophic status of a water body. The freshwater zooplankton fauna is grouped into five major types: Rotifera, Cladocera, Copepoda, Ostracoda and Protozoa. Among these, Cladocera commonly known as water fleas due to the jerky movements produced by their swimming antennae are important contributors to diversity (Bronmark & Hansson 1998; Pandit et al. 2016). They graze on detritus, bacteria and algae that shows their significance in nutrient recycling; and serve as food for both juvenile and adult planktivorous fishes (Pennak 1978) thus have potential economic importance as fish food organisms in aquaculture.

The Indian subcontinent has been blessed with different lentic and lotic water systems inhabited by Cladocera. The taxonomic studies on Cladocera were initiated by Baird (1860) and about 137 valid species have been reported till now. Region of Jammu & Kashmir also encompasses lentic and lotic water bodies which are abode to a wide variety of zooplankton species, including diverse Cladocera. Presently studied lentic water body of Jammu showed the presence of various zooplankton comprising 13 Cladocera species belonging to the families Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae, particularly including three different *Diaphanosoma* (Fischer, 1850) species of the family Sididae of order Ctenopoda. *Diaphanosoma* is the largest genus of ctenopods in group Cladocera and many of the species of this genus are known to be distributed in the tropics and subtropics (Korovchinsky 1986; Han et al. 2011). The species of this genus can be divided into two groups based on their body size, head size, size of swimming antennae and width of ventral shell margin (Korovchinsky 1986).

Kashmir valley experiences a temperate-cum-Mediterranean climate (Yousuf & Qadri 1981; Pandit et al. 2016) while Jammu lies in the subtropical type of climatic zone. *Diaphanosoma brachyurum* is a temperate and northern species (Fernando & Kanduru 1984; Sharma & Michael 1987; Han et al. 2011) and its occurrence has been reported from many water bodies of Kashmir (Yousuf & Qadri 1981; Pandit et al. 2016; Naik et al. 2017). Ironically, an earlier report of *Diaphanosoma brachyurum* has also been done from Jammu waters, therefore, raising a query regarding its distribution and identification. Presently, *Diaphanosoma brachyurum* has not been recorded and other three species viz. *Diaphanosoma senegal, Diaphanosoma excisum* and *Diaphanosoma sarsi* have been observed in the study pond.

Investigations on Cladocera diversity from various regions of Jammu division have been contributed by Gupta (2002), Sharma et al. (2005), Sharma & Chandrakiran (2011) and Sharma & Kotwal (2011), but the presently selected region remained totally unexplored due to which knowledge regarding this important fauna of Jammu is insufficient. Thus, this work was aimed to study the Cladocera diversity of a previously unexplored water body. In this paper, Cladocera fauna of the studied water body has been enlisted while special attention has been given to the three species belonging to the Sididae family which is taxonomically discussed in detail. Therefore, the present work updates the Cladocera record of J&K with the addition of three species new to the union territory and it deals with taxonomic identification, detailed and illustrated description, distribution and morphological comparison among three *Diaphanosoma* species recorded for the first time in Jammu & Kashmir.

MATERIAL AND METHODS

Study area: The present study area involves a subtropical pond located at 32.62˚N latitude and 74.87˚E longitude in tehsil Bishnah of Jammu district, J&K, India. It is a shallow pond surrounded by human habitation and agricultural fields. It is covered by vegetation all over its muddy embankment (Figure 1).

Methodology: Sampling was done for a period of one year from February 2019 to January 2020. Plankton samples were collected by filtering about 50 litres of water sample from the littoral zone through a plankton net made of bolting silk (no. 25). The filtrate was preserved by adding 4% formalin. The preserved specimens were stained with Rose Bengal stain and examined under an Olympus compound light microscope at 100x magnification. Minute structures were observed at 400x magnification. Measurements were taken with the help of an ocular micrometer and drawings were made with the help of camera lucida and Rotring Germany 1928 pens.

Quantitative estimation of zooplankton: For

Figure 1. Map showing the satellite view of the study station.

Table 1. List of Cladocera species reported from the study station.

Family	Cladocera species
Chydoridae	1. *Flavalona costata* (Sars, 1862)
	2. *Biapertura karua* (King, 1853)
	3.*Chydorus sphaericus* (Müller,1776)
	4.*Dunhevedia* sp.
	5. *Leydigia* sp.
Daphniidae	6. *Ceriodaphnia cornuta* (Sars, 1885)
	7. *Ceriodaphnia reticulata* (Jurine, 1820)
	8. *Simocephalus* sp.
Macrothricidae	9. *Macrothrix rosea* (Jurine, 1820)
Moinidae	10. *Moina brachiata* (Jurine, 1820)
Sididae	11. *Diaphanosoma excisum**
	12. *Diaphanosoma sarsi**
	13. *Diaphanosoma senegal**

*:- First record in Jammu & Kashmir

quantitative analysis, the drop count method was used and zooplankton number was calculated using formula (Adoni 1985):

Organism/litre = A*1/L*n/V

Where, A= No. of organisms in one drop

L= Vol. of original sample (l)

n= Total vol. of concentrated sample (ml)

V= Vol. of one drop (0.05ml)

The identification of Cladocera species was done by following Michael & Sharma (1988), Battish (1992), Edmondson (1992) and Korovchinsky (1992, 1993, 2004).

RESULTS

In the present investigation, 13 Cladocera species have been observed and morphologically identified. The recorded species belong to five families, viz., Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae. Among them, Daphniidae is represented by three species, Chydoridae by five species, Moinidae and Macrothricidae by a single species each, and Sididae by three species (Table 1). The species of family Sididae have been primarily focused and studied in detail.

Description of three *Diaphanosoma* species:

1. *Diaphanosoma senegal* Gauthier, 1951

It was first recorded and described by Gauthier (1951) from Senegal (western Africa). In India, this species was reported for the first time by Brehm (1952) as a new species which he named *D. hydrocephalus* but later changed it to *D. senegal*. Venkataraman & Krishnaswamy (1984) changed its name to *D. senegalensis,* but Korovchinsky (1992, 2004) found this name inappropriate with respect to International Rules of Zoological Nomenclature, so considered *D. senegalensis* as a junior synonym of *D. senegal.*

Female (Image 1A, Figure 2A): Size 0.6–0.7 mm. Sixteen female specimens were studied for the morphological characters.

Head large with well developed, protruding dorsal part; slanting anteriorly. Eye large, situated close to the ventral margin of head (Image 1B). A small depression exists between the head and trunk. Antennules short and thick, with a thick sensory seta bearing thin setules distally. Antennules are usually concealed under the swimming antennae.

Swimming antennae (Figure 2B) are long and robust, their ends do not reach up to posterior valve margin. The antennal basipodite is powerful and larger than its two branches. Upper branch or exopodite is longer and 2-segmented, lower branch is short and 3-segmented (endopodite).

Both the branches bear setulated setae on their segments except the small proximal segment of lower 3-segmented branch. Antennal setae have the formula 4-8/0-1-4. A thin spine is present on the distal end of proximal segment of exopodite while stout spines are present on the distal ends of second exopodite segment and outer two endopodite segments of antenna.

The dorsal margin of body is arched due to the hump present over the trunk. The valves are elongated and somewhat rectangular in shape (Image 1A). The posterior valve margins are evenly straight with a row of

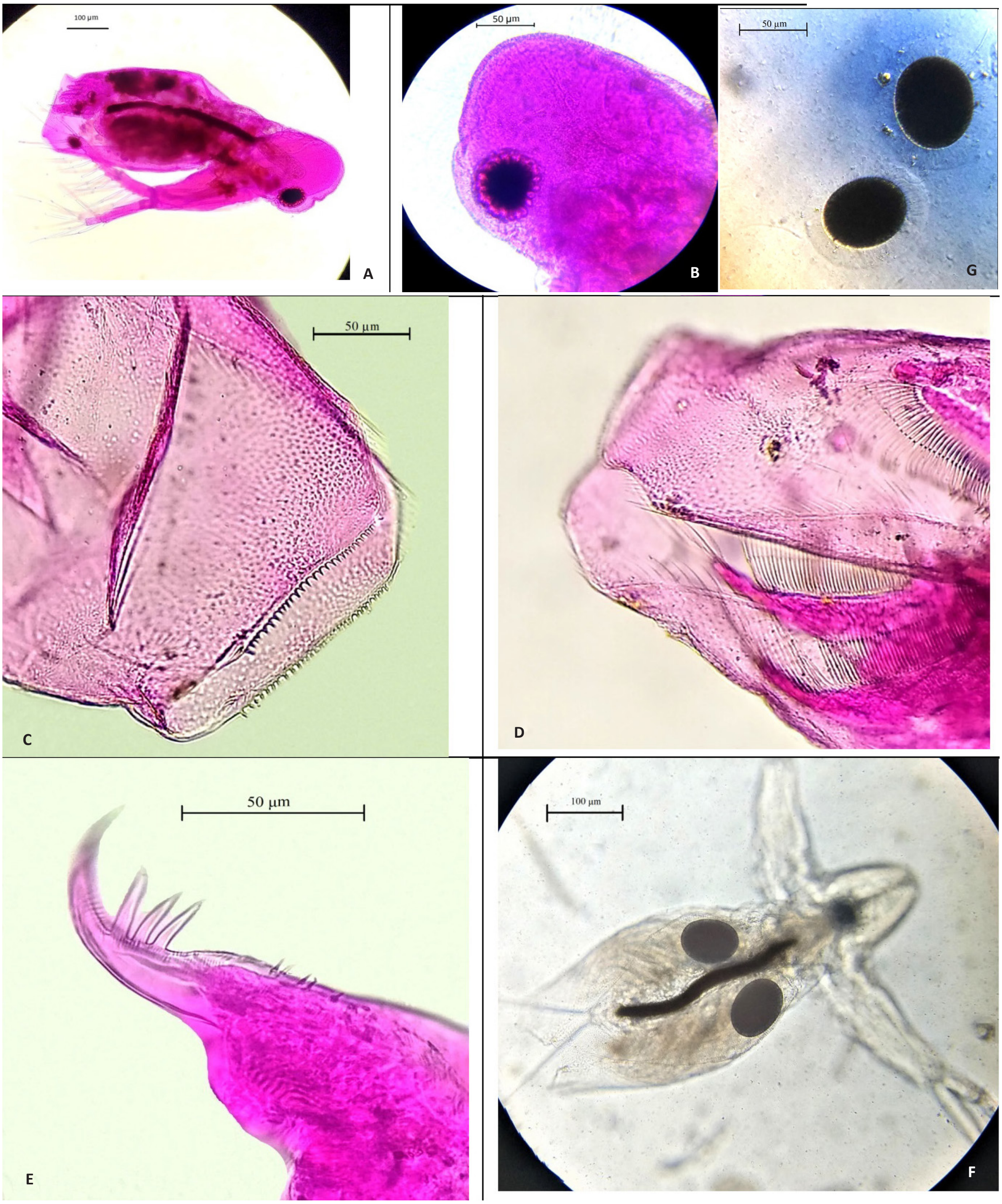

Image 1. (A–G). *Diaphanosoma senegal* Gauthier, 1951: A—Parthenogenetic female, lateral view | B—Head, lateral view (400x) | C—Posterior valve margins | D—Ventral valve inflexion | E—Postabdomen showing anal spines and setules on claw margin (400x) | F—Female carrying resting eggs, dorsal view | G—Resting eggs, lateral view.

27–55 (presently 25–35) denticles, dorsal or uppermost denticles larger and widely spaced than the lower ones (Image 1C, Figure 2C). The number of spines on both valves may vary in same individual. The ventral margin of valves has a wide inflexion narrowing distally and its edge bordered with many identical feathered setae

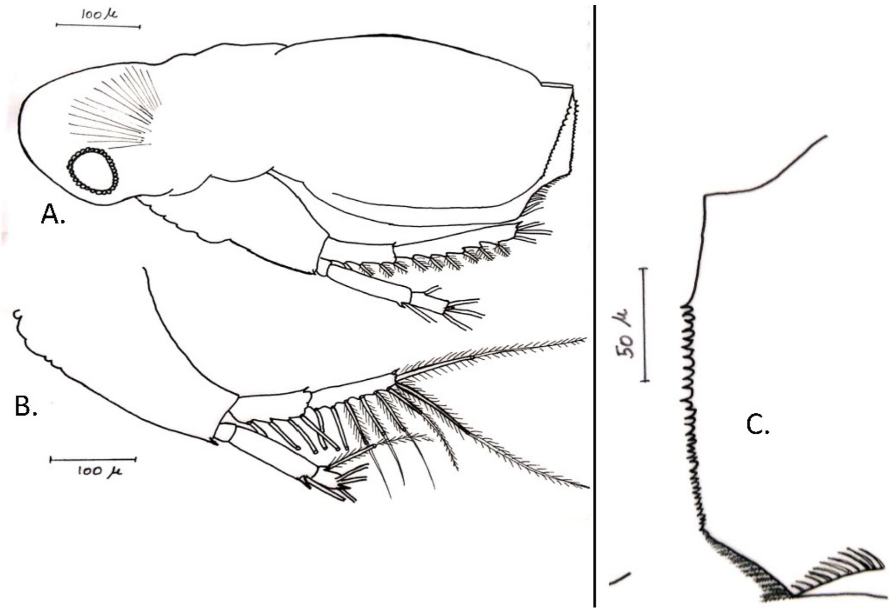

Figure 2 (A–C). ***Diaphanosoma senegal*** **Gauthier, 1951 (female): A—Adult female, lateral view | B—Second antenna of female | C—Posterior valve margin showing denticles and emargination.**

(Image 1D). The postero-ventral valve margins have deep emargination armed with about 10 short and thin feathered setae. Two small spines are present at the inner side of junction between posterior valve margins.

Postabdomen is small with sharp terminal claw bearing three robust basal spines. Setules are present at the concave margin of claw. About 6–7 anal denticles surrounded by many thin setules are present on the lateral sides of postabdomen (Image 1E, Figure 6A). These are usually present as doublets except one or two singlet also. Two long setae nanatoriae are present on the postabdomen.

Male (Image 2A): Size 0.40 – 0.45 mm. Seven male specimens were studied. Males are smaller in size than the adult females. They are easily distinguished from the females by the presence of very long antennules (about half of the body length) bearing thin setules on their surface being more numerous at the distal end (Image 2B, Figure 3B).

A very sharp, thick and large thorn is present at the outer distal end of antennal basipodite (Image 2C, Figure 3A). Two long, tubular copulatory appendages can be seen arising from near the postabdomen (Image 2D, 2E). These are broad proximally but get narrower at the distal end. The inner cavity of these appendages is clearly visible from outside (Figure 3C). Their posterior valve margins are seen armed with about 22–25 denticles (Figure 3D).

2. *Diaphanosoma excisum* Sars, 1885

Female (Image 3A): Size 0.45 – 0.51mm. Twelve female specimens were studied. Head is large, rectangular-shaped with well-developed dorsal part. Eye is relatively large and is situated antero-ventrally (Image 3B). Antennules short, but swimming antennae large and massive, not reaching at the posterior valve margins. A small spine is present at the distal end of basipodite. Short denticles are present at both the antennal branches.

Valves generally oblong but rather high in some of the individuals (Figure 4A). Posterior valve margins are rounded in outline, armed at the ventral corner with 4–18 (Korovchinsky 1992) large sharply pointed and backwardly directed denticles. Present specimens were bearing 8–14 such denticles (Image 3C).

The upper denticles are smaller in size than the lower ones. Number of denticles on both the valves of same individuals may vary. For instance, in one of the observed specimens, number of denticles were 11 on one valve while 14 on the other (Figure 4B).

The ventral valve margin is folded into a free flap that joins the valve at a right angle without any depression. It bears about 8–14 thin feathered setae (Image 3D).

The postabdomen is small with claw bearing three thin basal spines proximally decreasing in size (Image 3E, Figure 6B). Thin setules are present on the lateral sides of postabdomen (Image 3F).

3. *Diaphanosoma sarsi* Richard, 1894

Female (Image 4A, figure 5A): Size 0.37–0.42 mm. Nine female specimens were studied for their morphological characters. Head small, roundish-

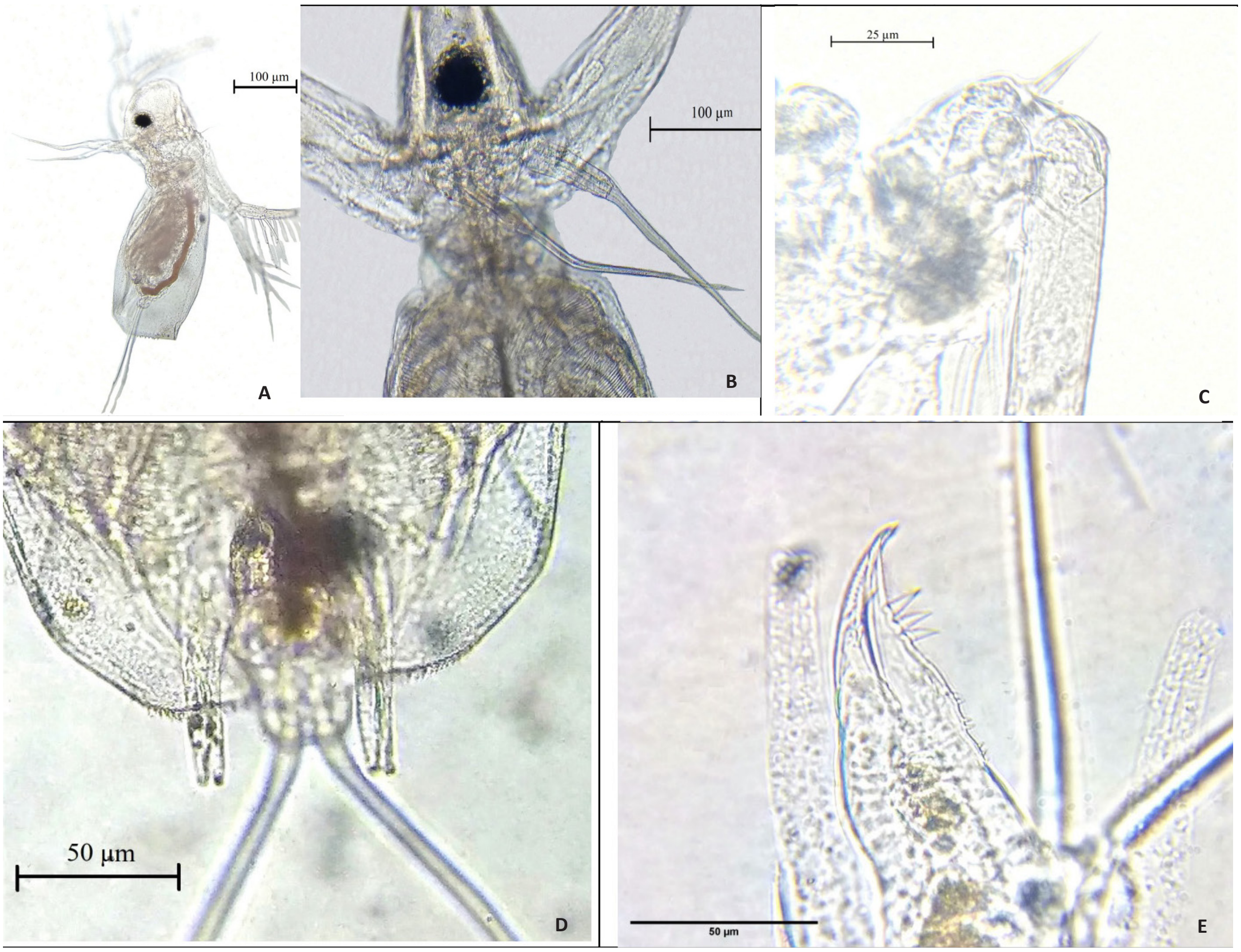

Image 2 (A–E). *Diaphanosoma senegal* Gauthier, 1951: A—Male, general lateral view | B—Male's antennules | C—Thorn on antennal basipodite | D—Copulatory appendages | E—Postabdomen of male (400x magnification).

rectangular with a little antero-ventral projection and sloping dorsal side. Eye very large covering most of the part of head (Image 4B). Antennules are short, covered by the second antennae. Swimming antennae are very long, but not reaching up to the posterior margin of the body. These are thin and weak (Image 4C).

A sharp spine and long seta are present at the outer and inner side of distal end of basipodite. Long denticles are present on the two branches of antenna in addition to the setae. Antennal setae have the formula 4-8/0-1-4.

The posterior valve margin is rounded and is armed with about 13–40 small denticles (Korovchinsky 1992) at the post-ventral region. Present specimens have shown the presence of 13–18 such denticles (Figure 5B). The size of the denticles gets reduced towards upper dorsal side (Image 4D). At the inner side of valve junction, two spines are present at both the valves.

Ventral part of valves is folded inwards forming a broad free flap, rounded distally and widens proximally. The inflexion is armed with 4–6 long thin feathered setae at the distal most region followed by 5–6 thorn like naked setae devoid of setules, which are again followed by long feathered setae (Image 4E).

Post abdomen is small and postabdominal claw is pointed, bearing three long thin basal spines and setules on its concave margin (Image 4F, Figure 6C).

Faunistics of *Diaphanosoma* species in India

Globally, the genus *Diaphanosoma* is dominant and abundant in the tropics and subtropics (Dumont 1994; Han et al. 2011) but few of the species belonging to this genus are confined to temperate region such as *D. brachyurum*. The presently recorded species of *Diaphanosoma* have been reported from many states of India (Figure 7) by several workers (Brehm (1952), Venkataraman & Krishnaswamy (1984), Michael & Sharma (1988), Venkataraman (1991, 1992, 2000), and Sharma & Sharma (2008). *Diaphanosoma sarsi* and *D.*

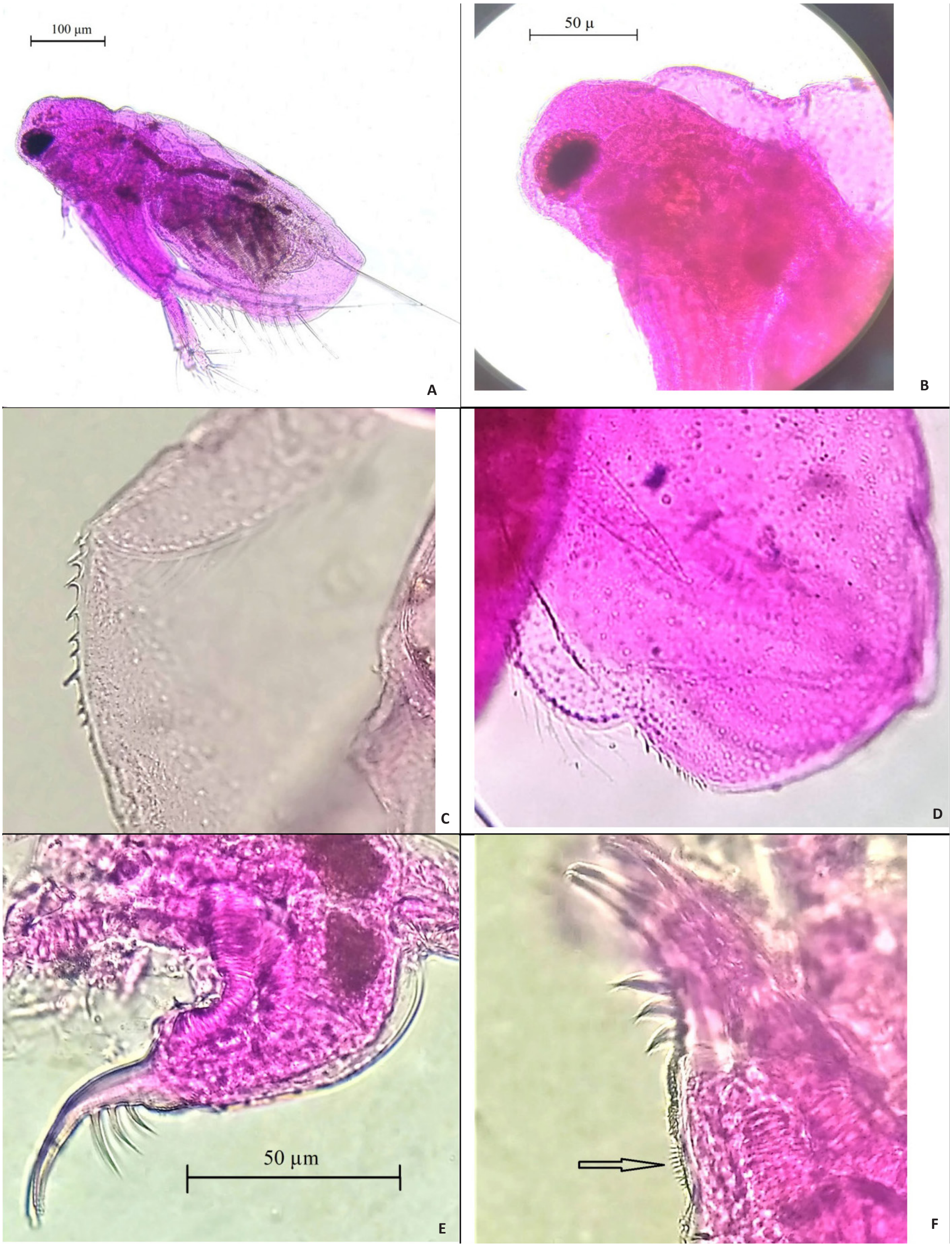

Image 3(A–F). ***Diaphanosoma excisum*****, Sars. 1885: A—Parthenogenetic female, lateral view | B—Head, lateral view (400x) | C—Posterior valve structure showing denticles | D—Ventral valve inflexion | E—Postabdomen, lateral view (400x) | F—Setules on postabdomen (400x).**

excisum are widespread in their occurrence (Chatterjee et al. 2013). Sharma & Sharma (2009) reported these three species from Loktak lake, Manipur having subtropical environment similar to the region under study. Among northern states of India, it is the very first record of the three species from J&K.

Venkataraman & Krishnaswamy (1984) recorded *D. senegal* from reddish-brown ponds of Tamil Nadu under the name *Diaphanosoma senegalensis.* The present record is the northernmost record of this species. *D. excisum* was first described from Australia by Sars (1885). There is a report of occurrence of this freshwater species from intertidal sandy beach, Odisha by Chatterji et al. (1995). *Diaphanosoma sarsi* was first described from Indonesia by Richard (1894). Nearest to J&K, its reports are from Punjab (Battish & Kumari 1986) which has a subtropical climate much similar to that of Jammu. In India, both *D. excisum* and *D. sarsi* commonly occur and are found throughout all the latitudes (south of 32°N) except Srinagar area of Jammu & Kashmir (Fernando & Kanduru 1984). From Jammu, they have been reported for the first time.

Morphological comparison among the three species

Diaphanosoma senegal has very specific morphological features that make it easily distinguishable from *D. excisum* and *D. sarsi*. But *D. excisum* and *D. sarsi* are morphologically close to each other whether it be the similarity in shape of valves or size (Table 2).

The presently examined specimens of all the three species are comparatively smaller in size than those described earlier by Korovchinsky (1992). The size of *D. senegal* recorded by Venkataraman & Krishnaswamy (1984) was 2.0 mm. According to Korovchinsky (1992), its size ranges 1.5–2.31 mm but in present sample, the largest female individual of *D. senegal* had attained a maximum size of 0.7 mm which is about half the size of the smallest adult female in the African (Korovchinsky 1991) and southeastern Asian samples (Korovchinsky & Sanoamuang 2008). According to Korovchinsky (1993), Asian individuals of *D. senegal* are comparatively smaller in size than the African ones.

Similarly, the sizes of *D. excisum* (0.45 – 0.51 mm) and *D. sarsi* (0.37 – 0.42 mm) are also small compared to that of Korovchinsky (1992), i.e., 0.63–1.30 mm and 0.64–1.20 mm, respectively.

Remarks on Biology

In the present study pond, *D. senegal* population was represented by juveniles, females and males while *D. sarsi* and *D. excisum* were represented by juveniles and females only. The month-wise population density of these three species has been given in Table 3.

Most of the mature females of *D. senegal* were carrying 2–3 embryos while a few were seen carrying about two resting eggs in their brood pouch (Image 1F).

The eggs were oval, dark greyish and surrounded by a transparent, thick jelly envelope (Image 1G). The purpose of this sticky jelly envelope is suggested to be the attachment to substrate like aquatic vegetation (Korovchinsky 1993).

Males were less in number (1 per two litres) than females (5 per two litres). The presence of males together with females can be attributed to the completion of sexual reproduction (Korovchinsky 1993) and production of resting winter eggs before the arrival of harsh and unfavourable winter season.

D. senegal individuals were present in the study pond in large density (about 30 individuals per litre) during the summer months. First appearance of *D. senegal* females was seen in the month of June when water was less turbid. Population density was the highest during the month of July when temperature and turbidity were high. Both males and females were present in August during monsoons. Its density (3 individuals per litre) remained high during monsoons, got reduced later in September and October when transparency was good, and disappeared in the following months (Table 3). It suggests the seasonality and their affinity for turbidity and high temperature.

Regarding the habitat, *D. senegal* is seen inhabiting temporary, shallow and highly fluctuating vegetated water bodies (ponds, rice fields) (Korovchinsky 1991, 1992, 1993). This further supports its existence in the present study pond which is shallow, vegetated, and fluctuates sometimes.

It has shown co-existence with *Moina brachiata* (Jurine, 1820), *D. excisum, D. sarsi, Ceriodaphnia cornuta* (Sars, 1885), *Macrothrix rosea* (Jurine, 1820), ostracod-*Onchocypris pustulosa* (Gurney, 1916) and calanoid copepod *Phyllodiaptomus blanci* (Guerne & Richard, 1896). Co-occurrence with similar type of fauna is also evident in the Asian samples of Korovchinsky (1993). Furthermore, Korovchinsky (1991) has also reported its co-existence with Cladocera like *Macrothrix* and *Moina*.

Only females of *D. sarsi* and *D. excisum* were found inhabiting the study pond. *D. excisum* was seen in abundance along with *D. senegal* during summer in July (18 individuals per litre) when the water was turbid but *D. sarsi* population was represented by fewer individuals at that time. The latter appeared in large numbers during post-monsoon period in October (3 individuals per two

Table 2. Comparison of morphological characters among three species of *Diaphanosoma*.

Morphological feature	*Diaphanosoma senegal*	*Diaphanosoma excisum*	*Diaphanosoma sarsi*
Size	0.6–0.7 mm	0.45–0.51 mm	0.37–0.42 mm
Shell	Rectangular	Oblong	Oblong
Head	Massive and slanting in front	Rectangular, moderate sized	Roundish, small sized
Shape and armature of posterior valve margin	Almost straight, Armed with numerous (25–35) spines throughout the margin, diminishing in size ventrally	Round at ventral angle, 8-14 denticles on postero-inferior region, diminishing in size dorsally	Round at ventral corner, 13–18 denticles dorsally decreasing in size.
Anal spines on postabdomen	Present	Absent	Absent
Ventral free flap	Wide proximally but narrows distally, armed with many identical setulated setae.	Narrow flap joins ventral valve margin almost perpendicularly.	Broad free flap round at distal end, armed with feathered as well as naked setae.

Table 3. Monthly population density (No./litre) of the three *Diaphanosoma* species reported from the study pond (February 2019 - January 2020)

Month / *Cladocera* sp.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan
Diaphanosoma senegal (female)	-	-	-	-	1.6	30.4	2.56	0.64	0.08	-	-	-
Diaphanosoma senegal (male)	-	-	-	-	-	-	0.56	-	-	-	-	-
Diaphanosoma excisum	-	-	-	-	-	18.08	0.32	0.56	0.56	-	-	-
Diaphanosoma sarsi	-	-	-	-	-	0.96	-	-	1.68	0.16		-

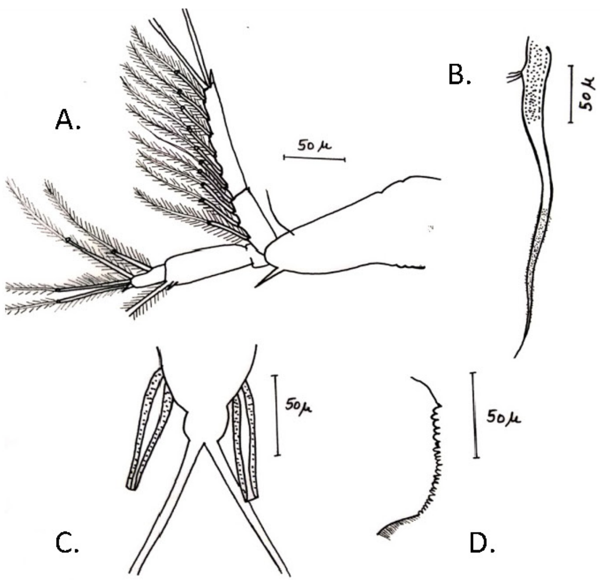

Figure 3 (A–D). *Diaphanosoma senegal* Gauthier, 1951 (male): A—Second antenna of male showing thorn like spine on basipodite | B—Antennule of male | C—Copulatory appendages | D—Posterior valve margin of male.

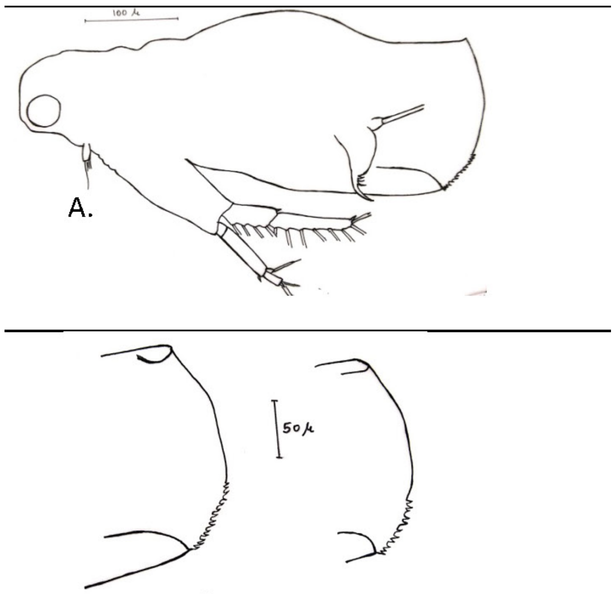

Figure 4 (A–B). *Diaphanosoma excisum* Sars, 1885 (female): A—Adult female, lateral view | B—Postero-ventral valve margins showing variable number of denticles on both valves of same individual.

litres) when water was clear and other two species were low in density.

D. excisum prefers different types of water bodies including the turbid ones or little brackish. *D. sarsi* generally inhabits the littoral zone of shallow and vegetated ponds, pools, rice fields etc. but can also be found in the pelagic zone of some large lakes (Korovchinsky 1992).

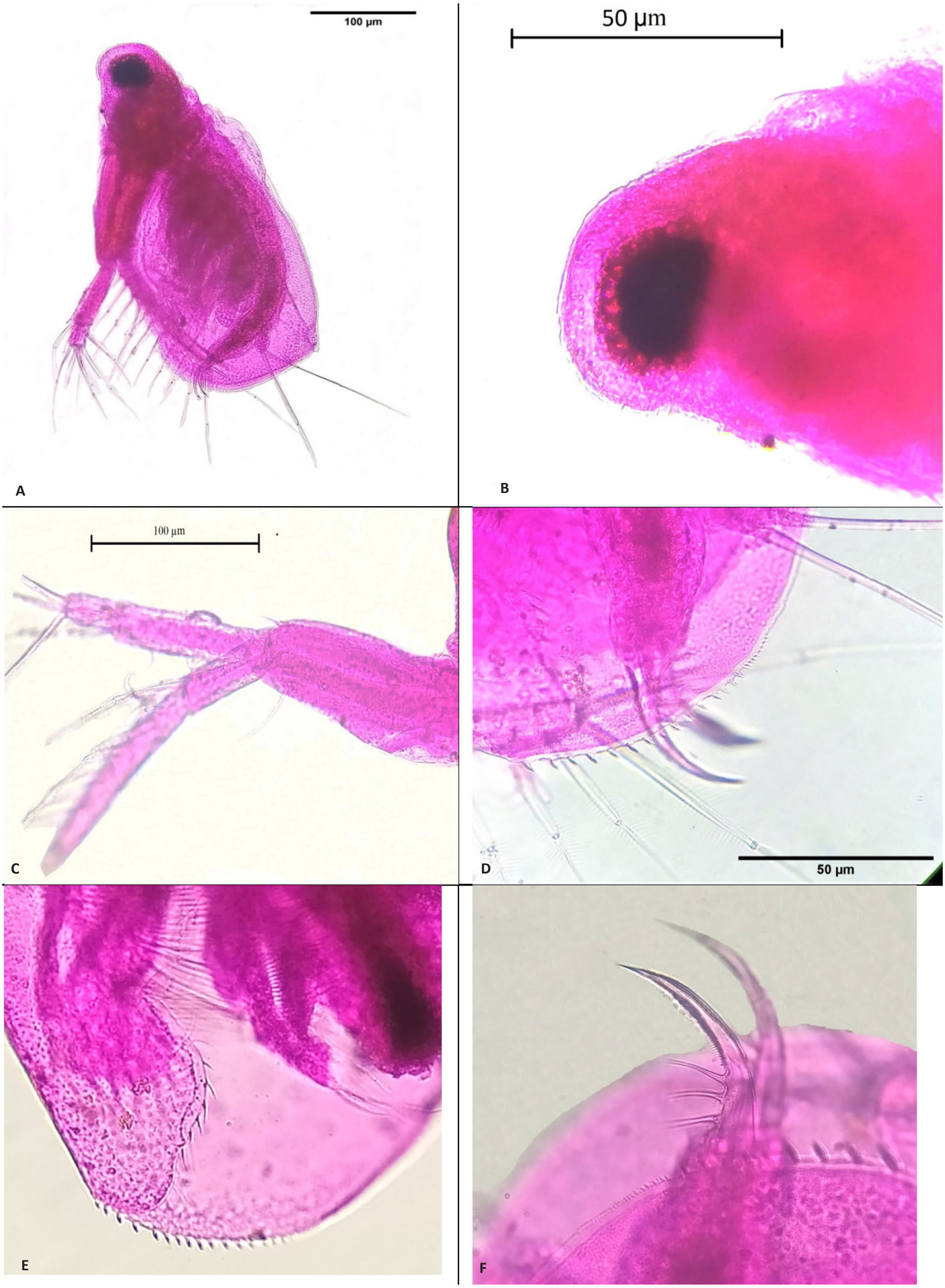

Image 4 (A–F). *Diaphanosoma sarsi* Richard, 1894: A—Adult parthenogenetic female (lateral view) | B—Head, lateral view (400x) | C—Swimming antenna | D—Posterior valve margin showing denticles | E—Ventral valve flap like inflexion (400x) | F—Post-abdominal claws (400x).

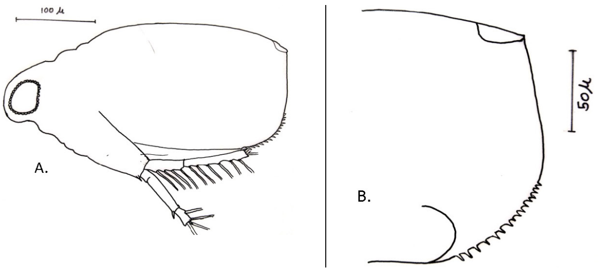

Figure 5 (A–B). *Diaphanosoma sarsi* Richard, 1894 (Female): A—Adult female, lateral view | B—Posterior valve margin showing denticles on postero-ventral region.

DISCUSSION

It is well known that the relative abundance of cladocerans can be affected by the presence of suspended sediments (Kirk & Gilbert 1990). Suspended sediments may affect zooplankton population both directly and indirectly. Indirect effects of suspended particles are mediated by decreased light penetration leading to decreased algal biomass and productivity (Hoyer & Jones 1983). This decrease in phytoplankton biomass may affect cladoceran population as their population growth is often limited by the abundance of phytoplankton (Tessier 1986). Other indirect effect of high sediment concentration involves the decreased ability of visual predators to locate their plankton prey (Hart 1988; Kirk & Gilbert 1990). Inhibitory effects of suspended sediments can be observed from the fact that Cladocera are known to ingest suspended clay particles (Arruda et al. 1983) for example, *Daphnia* can ingest particles in the size range 1–15 µm (De Mott 1982). This results in their decreased ingestion rate of phytoplankton cells, thus decreasing their population growth rate (Arruda et al. 1983). Such inhibition of phytoplankton ingestion is not observed for calanoid copepods and they are considered selective feeders (Bogdan & Gilbert 1984, 1987). Hart (1988) found that phytoplankton ingestion rate of *Daphnia* sp. was inhibited, but not that of calanoid copepod. This finding strongly supports the present abundance of calanoid copepod *Phyllodiaptomus blanci* and its co-existence with *Diaphanosoma* species in turbid water.

Kirk & Gilbert (1990) argued that fine clay particles did not inhibit Cladocera population, this suggests that turbid water species may have undergone specific changes in their morphology and behaviour to avoid ingestion of clay. Perhaps *Diaphanosoma senegal* and *Diaphanosoma excisum* may have adopted such a mechanism for better survival in a turbid environment. Shiel (1985) found that the mesh size of filtering thoracic appendages of *Daphnia carinata* individuals taken from turbid environment were larger when compared to the ones from clear water. In contrast to the inhibitory effects of suspended sediments on Cladocera population, few works have supported the abundance of Cladocera in silt laden water. Threlkeld (1986) reported that population of two Cladocera spp., *Moina micrura* Kurz and *Diaphanosoma leuchtenbergianum* Fischer, was increased during the period of high turbidity and their life table experiments have shown that they were capable to grow well in muddy waters. This further supports our observations on abundance of *D. senegal* and *D. excisum* in muddy conditions. Hart (1988) ranked *Moina brachiata* first in the ranking of 'turbidity tolerance'; this species was present in our study also.

Dissolved organic matter is adsorbed by suspended clay and in limiting food concentration, it can be used as supplementary food resource for freshwater filter feeders (Arruda et al. 1983). It may also regulate the abundance and differential species composition of zooplankton in turbid waters. Cladocerans are considered selective feeders (Sterner 1989) in terms of characteristics of food particles especially particle size. Pagano (2008) documented that *D. excisum* could not consume large

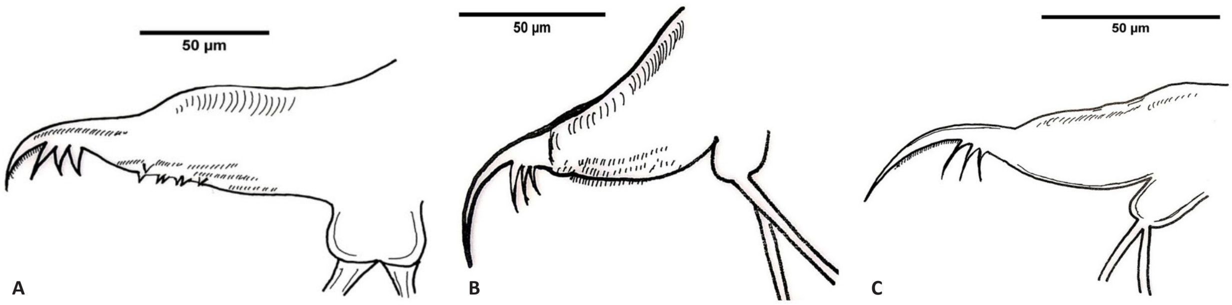

Figure 6 (A–C). Post abdomen, lateral view: A—*Diaphanosoma senegal* Gauthier, 1951 | B—*Diaphanosoma excisum* Sars, 1885 | C—*Diaphanosoma sarsi* Richard, 1894.

Figure 7. Distribution of *Diaphanosoma senegal, Diaphanosoma excisum*, and *Diaphanosoma sarsi* in India.

food particles but was restricted to smaller food items. Geller & Muller (1981) in their observations on the filtration apparatus of Cladocera, suggested that only one filter screen with a nearly constant filter mesh is present in *Diaphanosoma* species that restricts the size range of particles to be ingested. So, these species might have accepted only small sized clay particles adsorbed with organic matter and rejected large particles.

Now, from the above arguments, it can be inferred that higher abundance of *D. senegal* and *D. excisum* in turbid conditions can be due to the following reasons:

1. High turbidity provided greater protection from visual planktivore predators (Kirk & Gilbert 1990).

2. Due to high summer temperature, increased organic decomposition resulting into large concentration of detrital food might have reduced food constraints for them (Hart 1986), thus allowing them to attain large population size.

3. At limiting food concentration in turbid conditions, they might have employed different feeding strategy by ingesting small grains of silt adsorbed organic matter as additional source of carbon for maintaining their large population.

4. In order to be turbidity tolerant, they might have undergone adaptive changes in their feeding appendages.

It seems that the population of *D. sarsi* was controlled by the combined action of poor food availability and invertebrate predation. The possible influence of food limitation and invertebrate predation on the population size of *D. sarsi* can be examined by the findings that *D. sarsi* could not develop large population during lower food concentration at high turbidity but at higher transparency too, its population was not very large due to predation pressure by planktivore invertebrates (Dumont 1994) as increase in water transparency would have rendered it more vulnerable to visual predators. Similar results were obtained for *Daphnia gibba* Methuen population by Hart (1986).

Although temperature plays a major role in determining community structure but the presence of more no. of *D. sarsi* individuals during autumn months when transparency was high and lesser no. during hot summer months indicates that turbidity had overriding effect upon temperature (Hart 1986).

Thus, paucity in *D. sarsi* population in July could be attributed to food limitation and associated interference in collecting this limited food caused by high turbidity.

All the three species were absent in winter months, the likely causes for their winter decline or complete absence can be low primary productivity and existence of diapause in them.

REFERENCES

Adoni, A.D. (1985). *Work Book on limnology*. Pratibha Publishers, Sagar, 126pp.

Arruda, J.A., G.R. Marzolf & R.T. Faulk (1983). The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. *Ecology* 64: 1225–1235. https://doi.org/10.2307/1937831

Baird, W. (1860). Description of two new species of entomostracus crustacean from India. *Proceedings of Zoological Society of London* 28: 231–234.

Battish, S.K. (1992). *Freshwater zooplankton of India*. Oxford & IBH Publishing Co. Pvt .Ltd, New Delhi, 233pp.

Battish, S.K. & P. Kumari (1986). Effect of physico-chemical factors on the seasonal abundance of Cladocera in typical pond at village of Raqba, Ludhiana (India). *Indian Journal of Ecology* 13: 146–151.

Bogdan, K.G. & J.J. Gilbert (1984). Body size and food size in freshwater zooplankton. *Proceedings of the National Academy of Sciences (USA)* 81: 6427–6431. https://doi.org/10.1073/pnas.81.20.6427

Bogdan, K.G. & J.J. Gilbert (1987). Quantitative comparison of food niches in some freshwater zooplankton. A multi-tracer-cell approach. *Oecologia* 72: 331–340. https://doi.org/10.1007/BF00377560

Brehm, V. (1952). *Diaphanosoma hydrocephalus* nov. spec. Eine eigenartige Sididae aus Vorder-Indien. *Zoologischer Anzeiger* 149: 138–140.

Bronmark, C. & L.A. Hansson (1998). *The Biology of Lakes and Ponds*. Oxford University Press, Oxford.

Chatterjee, T., A. A. Kotov, K.V. Damme, S.V.A. Chandrasekhar & S. Padhye (2013). An annotated checklist of the Cladocera (Crustacea: Branchiopoda) from India. *Zootaxa* 3667(1): 001–089. https://doi.org/10.11646/zootaxa.3667.1.1

Chatterji, A., Z.A. Ansari, J.K. Mishra, P. Rattan & A.H. Parulekar (1995). Occurence of *Diaphanosoma excisum* (Sars) on a sandy beach at Balramgari (Orissa), India. *Hydrobiologia* 310: 157–161. https://doi.org/10.1007/BF00015534

DeMott, W.R. (1982). Feeding selectivities and relative ingestion rates of *Daphnia* and *Bosmina*. *Limnology and Oceanography* 27: 518–527. https://doi.org/10.4319/lo.1982.27.3.0518

Dumont, H.J. (1994). On the diversity of the Cladocera in the tropics. *Hydrobiologia* 272: 27–38. https://doi.org/10.1007/978-94-011-0884-3_3

Edmondson, W.T. (1992). *Fresh Water Biology*. (2nd edition), International Books and Periodicals Supply Service.

Fernando, C.H. & A. Kanduru (1984). Some remarks on the latitudinal distribution of Cladocera on the Indian Subcontinent. *Hydrobiologia* 113: 69–76. https://doi.org/10.1007/978-94-017-3612-1_4

Fischer, S. (1850). Ergänzungen, Berichtungen und Fortsetzungzu der Abhandlungüber die in der Umgebung von St. Petersburg Vorcommenden. Crustaceenaus der Ordnung der Branchiopoden und Entomostraceen. *Memoires de l' Academie des Sciences de St. Petersburg* 7: 1–14.

Gauthier, H. (1951). Contribution a l'etude de la faune des eauxdouces au Senegal (Entomostraces). Minerva, Alger, 172pp.

Geller, W. & H. Muller (1981). The filtration apparatus of Cladocera: filter mesh-sizes and their importance on food selectivity. *Oecologia* 49: 316–321.

Guerne, J.D. & J. Richard (1896). *Diaptomus blanci*, Copépode nouveau recueilli par M. Edouard Blanc à Boukhara (Turkestan). *Bulletin de la Société zoologique de France* 21: 53–56.

Gupta, S. (2002). Studies on the diversity of cladocerans in lake Mansar, Jammu. MPhil Dissertation, University of Jammu, Jammu.

Gurney, R. (1916). On some freshwater Entomostraca from Ceylon. *Proceedings of the Zoological Society of London* 86: 333–343.

Han, B.P., J. Yin, X. Lin & H.J. Dumont (2011). Why is *Diaphanosoma* (Crustacea: Ctenopoda) so common in tropics? Influence of temperature and food on the population parameters of *Diaphanosoma dubium*, and a hypothesis on the nature of tropical Cladocerans. *Hydrobiologia* 668: 109–115. https://doi.org/10.1007/s10750-010-0501-7

Hart, R.C. (1986). Zooplankton abundance, community structure and dynamics in relation to inorganic turbidity, and their implications for a potential fishery in subtropical Lake le Roux, South Africa. *Freshwater Biology* 16: 351–171. https://doi.org/10.1111/j.1365-2427.1986.tb00976.x

Hart, R.C. (1988). Zooplankton feeding rates in relation to suspended sediment content: potential influences on community structure in a turbid reservoir. *Freshwater Biology* 19: 123–139. https://doi.org/10.1111/j.1365-2427.1988.tb00334.x

Hoyer, M.V. & J.R. Jones (1983). Factors affecting the relation between phosphorus and chlorophyll a in mid- western reservoirs. *Canadian Journal of Fisheries and Aquatic Sciences* 40: 192–199. https://doi.org/10.1139/f83-029

Jurine, L. (1820). *Histoire des Monocies, quise trouvent aux environs de Genève*. Paschoud, Genf & Paris, 260pp.

King, R.L. (1853). On Australian Entomostraca—in continuation. *Papers and Proceedings of Royal Society of Tasmania* 2: 253–263.

Kirk, K.L. & J.J. Gilbert (1990). Suspended clay and the population dynamics of planktonic Rotifers and Cladocerans. *Ecological Society of America* 71(5): 1741–1755. https://doi.org/10.2307/1937582

Korovchinsky, N.M. (1986). On the taxonomy and geographical distribution of the superfamily Sidoidea Baird, 1850 (Crustacea: Cladocera). *Hydrobiologia* 140: 243–253.

Korovchinsky, N.M. (1991). The second record of *Diaphanosoma senegal* Gauthier, 1951 (Crustacea: Daphniiformes: Sididae) in Africa, with a redescription of the species and ecological and distributional setes. *Hydrobiologia* 222: 187–196. https://doi.org/10.1007/BF00016158

Korovchinsky, N.M. (1992). *Sididae & Holopediidae (Crustacea: Daphniiformes). Guide to the Identification of the microinvertebrates of the Continental Waters of the World. 3*. SPB Academic Publishing, The Hague, 82pp.

Korovchinsky, N.M. (1993). Description of the male, analysis of morphological variability and geographical distribution of *Diaphanosoma senegal* Gauthier, 1951. *Hydrobiologia* 259: 9–16. https://doi.org/10.1007/BF00005960

Korovchinsky, N.M. (2004). *Cladocerans of the order Ctenopoda of the world fauna (morphology, systematics, ecology, biogeography)*. KMK Press, Moscow, 410pp.

Korovchinsky, N.M. & L.O. Sanoamuang (2008). *Diaphanosoma senegal* Gauthier, 1951 (Crustacea: Cladocera: Sididae) in South-East Asia. *Zootaxa* 1695: 53–60. https://doi.org/10.11646/ZOOTAXA.1695.1.3

Michael, R.G. & B.K. Sharma (1988). *Fauna of India, Indian Cladocera***.** Zoological Survey of India, Calcutta.

Müller, O.F. (1776). *Zoologiae Danicae Prodromus, seu Animalium Daniae et Norvegiae Indigenarum characteres, nomina et synonyma imprimis popularium*. Typis Hallageriis, Havniae, 274pp.

Murugan, N., P. Murugavel & M.S. Kodarkar (1998). Cladocera: The biology, classification, identification and ecology. *Indian Association of Aquatic Biologists*, Hyderabad.

Naik, G., M.H. Balkhi, F.A. Bhat & M. Rashid (2017). Comparative study of present and past cladoceran diversity of Manasbal lake of Kashmir (India). *Journal of Fisheries Sciences* 11(1): 062–068.

Pagano, M. (2008). Feeding of tropical cladocerans (*Moina micrura, Diaphanosoma excisum*) and rotifer (*Brachionus calyciflorus*) on natural phytoplankton: effect of phytoplankton size– structure. *Journal of Plankton Research* 30(4): 401–414. https://doi.org/10.1093/plankt/fbn014

Pandit, A.K., J.A. Shah & G.M. Shah (2016). Research trends in cladoceran diversity from Kashmir Himalaya. *Proceedings of National Academy of Sciences, India* 86(2): 239 – 246. https://doi.org/10.1007/s40011-014-0480-y

Pennak, R.W. (1978). *Freshwater invertebrates of United States 2nd Ed*. John Willey Sons Inc., New York.

Richard, J. (1894). Entomostracesrecueillis par M.E. Modigliani dans le lac Toba (Sumatra). *Annali del Museo Civico di Storia Naturale di Genova* 14: 565–578.

Sars G.O. (1862). Hr. studios. Medic. G.O. Sars fortsatte sit Foredrag over de af ham i Omegnen af Christiania iagttagne Crustacea cladocera. *Forhandlinger i Videnskabs–Selskabet i Christiania* 1861: 250–302.

Sars, G.O. (1885). On some Australian Cladocera, raised from dried mud. *ForhandlingeriVidenskabs- Selskabeti Christiana* 1–46.

Sharma, B.K. & R.G. Michael (1987). Review of taxonomic studies on freshwater Cladocera from India with remarks on biogeography. *Hydrobiologia* 145: 29–33.

Sharma, B.K. & S. Sharma (2008). Zooplankton diversity in floodplain lakes of Assam. *Records of Zoological Survey of India* 290: 141–307.

Sharma, B.K. & S. Sharma (2009). Faunal diversity of Cladocera (Crustacea: Branchiopoda) of Loktak Lake (A Ramsar site) Manipur (N.E. India). *Journal of the Bombay Natural History Society* 106(2): 156–161.

Sharma, K.K. & S. Chandrakiran (2011). Comparative analysis of cladoceran communities from three subtropical freshwater ponds of Jammu: Patterns, Composition and Diversity. *The Bioscan* 6(2): 233–237.

Sharma, K.K., S. Kour & S. Gupta (2005). Distributional pattern of cladoceran in subtropical lake, Mansar, J&K. *National Journal of Life Sciences* 2(12): 23–26.

Sharma, K.K. & S. Kotwal (2011). Studies on diversity and dynamics of Cladocera in a subtropical Sungal pond Akhnoor (J&K). *The Bioscan* 6(4): 623–625

Shiel, R.J. (1985). Zooplankton of the Darling River system, Australia. *Internationale Vereinigung fur theoretische und angewandte Limnologie, Verhandlungen* 32: 2136–2140. https://doi.org/10.1080/03680770.1983.11897637

Sterner, R.W. (1989). The role of grazers in phytoplankton succession, pp. 107–170. In: Sommer, U. (ed.), *Plankton Ecology: Succession in Plankton Communities*. Springer Verlag, Berlin. https://doi.org/10.1007/978-3-642-74890-5_4

Tessier, A.J. (1986). Comparative population regulation of two planktonic Cladocera (*Holopedium gibberum* and *Daphnia catawba*). *Ecology* 67: 285–302. https://doi.org/10.2307/1938573

Threlkeld, S.T. (1986). Life table responses and population dynamics of four cladoceran zooplankton during a reservoir flood. *Journal of Plankton Research*. 8: 634–647. https://doi.org/10.1093/plankt/8.4.639

Venkataraman, K. & S. Krishnaswamy (1984). A new record of *Diaphanosoma senegalensis* Gauthier, 1951 (Cladocera, Sididae) from Madurai, South India. *Current Science* 53(19): 1041–1042.

Venkataraman, K. (1991). Freshwater Cladocera of Little Andaman. *Journal of the Andaman Science Association* 7(2): 43–49.

Venkataraman, K. (1992). Cladocera of Keoladeo National Park, Bharatpur and its environs. *Journal of the Bombay Natural History Society* 89: 17–26.

Venkataraman, K. (2000). Freshwater Cladocera (Crustacea: Branchiopoda) of the Andaman & Nicobar Islands. *Journal of the Bombay Natural History Society* 97: 67–73.

Yousuf, A.R. & M.Y. Qadri (1981). Ecology of *Diaphanosoma brachyurum* Lieven (Cladocera: Crustacea) in lake Manasbal, Kashmir. *Journal of Indian Institute of Sciences* 63(C): 35–42.

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