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Systematic descriptions and seasonal variations of mollusc in Chandigarh (U.T., India) and its surrounding freshwater bodies

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Abstract
The present study is the first attempt to study the taxonomy and diversity of molluscan fauna from freshwater bodies of Chandigarh (U.T.) and Ghaggar River flowing on its southeast border. A total of 24 molluscan species (17 gastropods, 3 bivalves and 4 land snails) were collected from the selected sites. *Physa acuta* was found showing ubiquitous occurrence along with its maximum abundance in all water bodies followed by *Melanoides tuberculata*. Less biodiversity and the presence of tolerant species indicated that majority of the water bodies under study are under a great threat of degradation. The results of this study will contribute to the knowledge of the regional malacofauna along with identification of the sites facing natural and human interferences.

Keywords: Gastropods, land snails, bivalves, taxonomy, biotic indices

1. Introduction
Globally freshwater ecosystems and their inhabitants are facing more decline than terrestrial and marine ones. Of all freshwater ecosystems, lakes, ponds and pools are extremely threatened and their biotic conservation is very difficult since they have a higher level of endemism, owing to their natural isolation while for rivers the same holds true because of the presence of saltwater barriers which impair re-colonization of declined or lost fauna [1-3]. In addition, these bodies have a special landscape position hence get more prone to all the changes and disturbances that happened in their adjacent terrestrial areas [4].
Freshwater molluscs (mussels and snails), like other macro-invertebrates, are vital components of any aquatic ecosystems. Their sensitivity to the habitat's conditions allows them to act as biological indicators of the health of their habitats. They also play multiple roles in their ecosystems like, food source for many animals, nutrient cycling, decomposition etc. [5, 6]. Molluscs with their attractive shells are economically important in many different ways of commerce [7]. Freshwater molluscs are also known for their significant role in the public and veterinary health, by acting as intermediate host of helminths parasites. Hence, there is a great need to explore their diversity.
Literature suggested that Preston was the first to document Indian freshwater molluscs in his book, "Preston's-Fauna of British India" in which he reported around 370 species of freshwater Gastropods and Pelecypods from the then undivided India, Burma and Ceylon [8]. Few other researchers like Annandale and Subba Rao, also made remarkable attempts to identify and report these shelled animals from different parts of India. Subba Rao reported 195 species of molluscs from India and its adjoining areas in his manuscript "Freshwater Molluscs of India" [9]. Later on many Indian scientists start showing their interest in the taxonomy of molluscs. But most of them worked on the marine molluscan fauna and a very little importance has been given to their freshwater representatives.
The molluscan taxonomy of North Indian states was undertaken by few malacologists especially from Jammu and Kashmir [10-12], Uttrakhand [13, 14], Himachal Pradesh [15-17], Uttar Pradesh [18, 19] and Punjab [20, 21]. The molluscan fauna of Haryana (a North Indian state) and its capital Chandigarh (U.T., India) did not attract any worker from this important task. While reviewing the concerned literature from the state, some single number papers were found

recording molluscan biodiversity from Haryana [22, 23].

While laying down the blue print for the first planned city of post-independent India, Chandigarh (U.T.), Le Corbusier a Swiss-French architect and his team deliberately treasured the natural province of the city with some freshwater bodies (N-Choe, Sukhna Choe and Patiala Ki Rao) for checking against its flooding, beautifying the vicinity and providing a healthy and habitable environment for aquatic flora and fauna. Of these three streams, N-Choe a seasonal rivulet is passing through the centre of the city and its flow is dependent on the rainwater during monsoon season. Since beginning it was in a very healthy condition harbouring many aquatic animals but from the last couple of decade's demographic expansion and administrative neglect has turned it to a stinking drain. Currently it houses only a few tolerant representatives of molluscs, annelids and arthropods.

On the southeast outskirts of Chandigarh, another seasonal river, the Ghaggar River, is flowing which depends on the monsoon rainfall as well. Ghaggar River too is facing a lot of human intrusions in one or other way which finally leads toward its degradation. The factors like idol immersions, washing, bathing, constructions etc. are found responsible for its awful condition. Out of two different lakes in Chandigarh *viz*. Sukhna Lake and Dhanas Lake, latter has been found facing the decline in its water quality.

The current study was focused on the collection and identification of the malacofauna from different sites of Ghaggar River (in Panchkula, Haryana, India), N-Choe, Sukhna Lake and Dhanas Lake (Chandigarh, U.T., India) over a period of two years along with their seasonal community dynamics.

2. Objective of the study

- Collection and Identification of the molluscan biodiversity from freshwater bodies of Chandigarh and Haryana.
- Analyze the seasonal variations in the molluscan biodiversity from the selected water bodies.

3. Materials and Methods

3.1 Study area and sampling sites

Site 1 and Site 2: Ghaggar River (29.60^0 N, 75.02^0 E) originates in Himachal Pradesh and flows through Punjab, Haryana and Rajasthan. It is an endorehic river which flows during monsoon season and for the rest of the year it was found supporting less amount of water. For malacofauna collection two stations, an upstream and a downstream, were selected on the river in Panchkula district (Haryana) which borders the UT Chandigarh.

Site 3 and Site 4: N-Choe (30.76^0 N, 76.81^0 E) originates from behind the Panjab-Haryana High Court complex and passes through sector 5, 10, 16, 23, 36 and 42 and finally enter into S.A.S. Nagar/Mohali (Panjab). It is a natural, freshwater, seasonal and rainwater fed stream. Two stations were selected on the stream for sample collection, an upstream and a downstream.

Site 5: Sukhna Lake (30^044' N, 76^049' E) is a manmade lake situated at foothills of Shivalik hills. Its surface area is 3 km^2 with an average depth of 2.43 m and maximum depth of 4.87 m.

Site 6: Dhanas Lake (30^045' N, 76^045' E) is located on the west end of Chandigarh and a part of it is located in Patiala Ki Rao reserve forest. The lake supports rich algal growth (Figure 1 and Table 1).

Fig 1: Location of study areas and sampling sites

Table 1: Description of sampling stations of Ghaggar River and N-Choe

Site	Station	Site codes
Ghaggar River	Upstream (Nada Sahib, Panchkula, Haryana)	S1
	Downstream (Nada Sahib, Panchkula, Haryana)	S2
N-Choe	Upstream (Leisure valley, Sector-10, Chandigarh)	S3
	Downstream (Government Girls College, Sector-42, Chandigarh)	S4
Sukhna Lake	Behind silence garden	S5
Dhanas Lake	Dhanas village behind reserve forest	S6

3.2 Sample Collection

Both living as well as dry shells were collected. Shell's collection was done both by hand picking and soil sampling method using a modified Dandy's sampler. Soil samples were carried to the laboratory in polythene bags. Empty shells were cleaned with soft brush and were stored in plastic viols and zip-locks in storage wooden boxes. The soil samples were sieved using standard sieve set (as per IS:460) of different mesh sizes (BSS 75mm, 44mm, 30mm, 10mm and 4mm), shells were handpicked from sieves. Live gastropods were put in Luke warm water. On extension of head and foot, the soft body of the animal was taken out by inserting the pin in the foot and twisting the shell. Later shells were cleaned by soft brushes and living tissues were preserved in 5% formalin. The molluscs were identified up to species level, based on the shell characteristics [9, 24] and anatomical features [25].

4. Results

In the present study, 24 species of molluscs (17 gastropods, 3 bivalves and 4 land snails) were collected from different stations of Ghaggar River, N-Choe, Sukhna Lake and Dhanas Lake (Table 2).

Key to families (freshwater snails)

1	Shell univalve ----------	**2(Gastropoda)**
	Shell bivalve ----------	**7 (Pelecypoda)**
2	Shell sinistral or dextral ----------	**3**
	Shell always sinistral----------	**Physidae**
3	Shell oblong or ovate with long or raised spire ----------	**4**
	Shell discoidal with depressed spire ----------	**Planorbidae**
4	Shell operculate----------	**5**
	Shell non-operculate----------	**Lymnaeidae**
5	Operculum with spiral growth lines----------	**6**
	Operculum with concentric growth lines ----------	**Viviparidae**
6	Shell turreted, operculum shape not similar to aperture----------	**Thiaridae**
	Shell turreted or elongate, operculum similar in shape to aperture----------	**Hydrobiidae**
7	Shell internally nacreous, umbones raised, hinge with lateral and pseudo cardinal teeth, sculpture radial and well developed----------	**Unionidae**

Table 2: Classification of collected molluscan species and their occurrence at selected sites.

Phylum	Class	Family	Genus	Species	S1	S2	S3	S4	S5	S6
Mollusca	Gastropoda	Physidae	*Physa*	*acuta*	+	+	+	+	+	+
		Planorbidae	*Gyraulus*	*euphraticus*	-	-	+	-	+	-
			Gyraulus	*convexiusculus*	+	-	+	-	+	-
			Indoplanorbis	*exustus*	-	+	-	-	+	-
		Lymnaeidae	*Lymnaea*	*mimetica*	-	-	-	-	+	-
			Radix	*persica*	-	-	+	-	+	-
			Radix	*acuminata*	-	-	+	-	+	-
			Radix	*biacuminata*	-	-	-	-	+	-
			Radix	*luteola*	+	+	-	-	+	-
			Radix	*luteola ovalis*	-	-	-	-	+	-
			Galba	*truncatula*	-	-	+	+	-	+
		Viviparidae	*Filopaludina*	*bengalensis typica*	-	-	-	-	+	-
			Filopaludina	*bengalensis mandiensis*	-	-	-	-	+	-
			Idiopoma	*dissimilis*	-	-	-	-	+	-
		Thiaridae	*Melanoides*	*tuberculata*	-	+	+	+	+	-
			Thiara	*rudis*	-	-	-	-	+	-
		Hydrobiidae	*Gabbia*	*travancorica*	-	-	-	-	+	-
	Bivalve	Unionidae	*Lamellidens*	*marginalis*	-	-	-	-	+	-
			Lamellidens	*corrianus*	-	-	-	-	+	-
			Parreysia	*Caerulea*	-	-	-	-	+	-
	Land Snail	Ariophantidae	*Macrochlamys*	*indica*	-	-	-	-	-	-
		Subulinidae	*Opeas*	*gracile*	-	-	-	-	+	-
			Zootecus	*insularis*	-	-	-	-	+	-
		Cerastuidae	*Rachis*	*punctatus*	-	-	-	-	+	-

3.3 Systematic description of freshwater molluscs

Class: Gastropoda

Subclass: Pulmonata

Superorder: Basommatophora

Family: Physidae

Physidae is the family of freshwater pulmonates and is found world-wide. The shells of this family are always sinistral (coiling to the left or anticlockwise spirally coiled), comparatively small with an acute and posteriorly directed spire and distinguished by lack of an operculum. In India, the family is represented by only one genus, *Physa*.

Physa acuta (Draparnaud, 1805)

Taxonomic description- Shell sinistral, non-operculate, elongate-ovate, thin, light fawn coloured, smooth, moderately lustrous and translucent; fine, close set lines of growth; protoconch distinct; number of whorls 5, regularly and rapidly decreasing in size; apex pointed; spire short; sutures slightly impressed; aperture large, about three-fourth of shell's total length; outer lip thin, slightly deflected out; umbilicus closed; parietal callus wide, columella well-marked.

Family: Planorbidae

The Planorbids are hermaphroditic and non-operculate. The shells of this family may be discoidal or planispiral, dextral or sinistral. They inhabit clear freshwater (stagnant or slow running), live on aquatic vegetation and feed on minute algae and fine organic deposits. Few species are also reported as the intermediate hosts for several trematode parasites.

Gyraulus convexiusculus (Hutton, 1849)

Taxonomic description- Shell dextral, non-operculate, discoidal, very small, greatly depressed, smooth, glossy, pale horny brown coloured, periphery subangulate; number of whorls 4, rounded, widely coiled, last whorl covers the shell; body whorl not ribbed; spire sunken; sutures well defined; aperture oblique, oval shaped; lips simple; umbilicus wide and deep.

Gyraulus euphraticus (Mousson, 1874)

Taxonomic description- Shell dextral, non-operculate, discoidal, very small, thin, greatly depressed, narrow, peripheral angle slightly keeled, more compressed and strongly carinate, more opaque and coarser than *G. convexiusculus*; number of whorls 3; sutures deep; irregularly sculptured with longitudinal and spiral stripes, striations very fine but visible; umbilicus narrow.

Indoplanorbis exustus (Deshayes, 1834)

Taxonomic description- Shell sinistral, non-operculate, discoidal, thin, dorso-ventrally flat, creamish-brown coloured, surface transpirally ridged; body whorl large and greatly expanded; penultimate whorl very narrow; number of whorls 4; spire depressed; sutures deeply impressed; aperture ear shaped; umbilicus wide; callus developed; inner peristome fused with body whorl, outer peristome reflected outwards, rounded at periphery.

Family: Lymnaeidae

Lymnaeidae family is having world-wide distribution. Its maximum diversity is found in the northern part of North America. The shells of this family are dextral showing varied sizes, from small to medium and variable shapes, globular to attenuate. They live in shallow waters, where temperature is generally found high and more food for them is available. Few exceptional species are known to inhabit deep lakes. They also act as vectors of helminths parasites that severely affect human and livestock as well.

Lymnaea mimetica (Annandale, 1918)

Taxonomic description- Shell dextral, non-operculate, small, thin, fragile, oblong, pale or cream coloured; number of whorls 3; body whorl narrow; spire short; apex blunt; columellar callus absent; aperture oblong, outer lip thin and sharp.

Radix persica (Issel, 1865)

Taxonomic description- Shell dextral, non-operculate, large, inflated, whitish to creamish, sculptured with transpiral striae; number of whorls 4, body whorl large, inflated; spire short, sunken, pointed and acuminated; aperture large, obliquely placed, greatly expanded; columellar fold highly developed, twisted, fold occludes umbilicus, callus well developed, gets sharply narrowed below twist.

Radix acuminata (Lamarck, 1822)

Taxonomic description- Shell dextral, non-operculate, thin, fragile, oblong-ovate, glossy, smooth, sculptured with fine and feeble vertical lines without spiral ridges; number of whorls four and half, body whorl inflated; spire short, acuminate, apical whorls somewhat flattened, forming an acute spire, separated by a very oblique suture; aperture large, wide; number of whorls 4-5; umbilicus imperforate; columellar fold prominent, twisted; callus whitish and well developed.

Radix biacuminata (Annandale and Rao, 1925)

Taxonomic description- Shell dextral, non-operculate, thin, large, fragile, narrow, elongate, spindle shape, sculptured with curved longitudinal striae, pale luteous colour; number of whorls three and half; aperture large, ovoid; columellar callus well developed, slightly twisted with a broad fold; umbilicus completely occluded.

Radix luteola (Lamarck, 1822)

Taxonomic description- Shell dextral, non-operculate, small, ovate, smooth, glossy, pale yellow colour with whitish bands; number of whorls three and half, body whorl inflated, broad at anterior end; spire conical, less pointed placed little laterally to body whorl; sutures traverse, length of suture at base of spire almost equal to height of spire; aperture ovate, narrow, rounded below; umbilicus closed; callus very less developed, translucent; inner peristome fused with body whorl, outer peristome thin.

Radix luteola ovalis (Gray, 1822)

Taxonomic description- Shell dextral, non-operculate, thin, ovate, brownish coloured, broad base; number of whorls 4; spire small, exerted, acuminated; body whorl large, quite inflated; apex pointed; sutures transverse; aperture oval,

peristome thin, simple; columella spirally twisted.

Galba truncatula (Müller, 1774)

Taxonomic description- Shell dextral, non-operculate, small, elongate-oval, slender, conical, smooth, nearly twice as high as broad, light brownish or straw coloured, more or less transparent, striae transpiral, fine, closely arranged; number of whorls 4, convex, oblique, slightly shouldered; spire gradually increasing in size; body whorl not much inflated; sutures, deep, impressed; aperture narrow, almost equally long as body whorl, rounded at the base with little reflected peristome; umbilical pore prominent; columellar callus not much developed, callus formation after the twist.

Subclass: Prosobranchia
Superorder: Mesogastropoda
Family: Viviparidae
Viviparidae is a family of freshwater, operculate snails from rivers, ponds and lakes. The shells of this family are thick, globose, and dextral with size varying from medium to large. They live in still or slow moving waters and are usually nocturnal. The members of this family are found amongst vegetation, in sand or mud. Many species during drought conditions burrow themselves in mud and seal their operculum.

Filopaludina bengalensis typica (Lamarck, 1822)

Taxonomic description- Shell dextral, operculate, medium sized, conical in outline, yellowish brown colour; number of whorls 6, plano-convex, dark bands spirally arranged, irregular pattern of thick and thin bands; sutures impressed; body whorl evenly convex, greatly swollen; penultimate whorl broad; spire pointed, height equal to body whorl; aperture sub circular with narrow black margin; umbilicus widely open; operculum horny, deep brown, eccentric nucleus, deep red area around the nucleus; columellar callus developed; inner peristome clearly visible, thick rim like, not fused with body whorl, outer peristome thick.
Filopaludina bengalensis mandiensis (Lamarck, 1822)

Taxonomic description- Shell dextral, operculate, medium sized, more conical than *typica*, greenish brown colour, number of whorls 6, more convex than *typica*, broad and narrow dark spiral bands arranged alternately; sutures less impressed than *typica*; body whorl evenly convex; penultimate whorl less broader than *typica*; spire with pointed apex, height almost equal to body whorl; aperture ovoid; operculum horny, deep brown, eccentric; umbilicus narrowly open; columellar callus well developed; inner peristome not distinct, thin fused with body whorl, outer peristome thin.
Idiopoma dissimilis (Müller, 1774)

Taxonomic description- Shell dextral, operculate, ovately conical, small, dirty olive green coloured; spire broadly conical and swollen; sutures deeply impressed; whorls inflated, number of whorls four and half; body whorl with slightly elevated ridge, without dark spiral bands; aperture ovate; umbilicus narrow; operculum thick.

Family: Thiaridae
Thiaridae is a family of tropical freshwater snails with an operculum and are commonly named as thiarids or trumpet snails. The shells of this family are dextral, elongated, conical, and turreted and are micro sculptured with spiral ridges. They inhabit both lotic and lentic freshwater bodies, though some taxa are also found tolerating brackish conditions. They bury themselves in mud or sandy bottoms or are found attached to rocks.
Melanoides tuberculata (Müller, 1774)

Taxonomic description- Shell dextral, operculate, slender, turreted and conical, dark reddish-brown dots and flames distributed irregularly and longitudinally arranged on the shell surface; body whorl large and swollen, sculptured with vertical ribs and spiral striae, sculpturing more prominent on upper whorls than lower; number of whorls 10; spire high; aperture pyriform, pointed above and rounded below; umbilicus imperforate, outer peristome red rimmed; columellar callus translucent anteriorly and whitish posteriorly; operculum paucispiral, nucleus placed near the base of operculum.
Thiara rudis (Lea, 1850)

Taxonomic description- Shell dextral, operculate, turreted to sub cylindrical, thick, cream or brownish cream colored, sculptured with axial ribs and spiral ridges often in the beaded form; spire high; number of whorls 8; aperture pear shaped.

Family: hydrobiidae
Hydrobiidae is one of the largest gastropod families which consist of cosmopolitan group of small freshwater snails. They form the major biotic component of inland waters owing to their ubiquity and diversity. The shells of this family are small, dextral, ovately conical or turreted with operculum which is similar to aperture in shape.
Gabbia travancorica (Benson, 1860)

Taxonomic description- Shell dextral, operculate, small, conically globose, white coloured; spire high, broadly conical; body whorl not much swollen; number of whorls 4, obliquely rounded; sutures impressed; columella ridge like, descending almost straight, imperforate; aperture oval, faint whitish thin rim around the aperture.

Class: Bivalvia
Subclass: Paleoheterodonta
Order: Unionoida
Family: Unionidae
Unionidae family is commonly referred as pearly mussels or unionids, and are found in freshwater habitats globally. These bivalves are the inhabitants of permanent freshwater sources like lakes, streams and rivers. The shells of this family are internally nacreous having equilateral valves with raised umbones and well developed radial sculptures. They are the key members of aquatic ecosystems and plays very vital ecological role like nutrient cycling, bio-turbation, water purification etc.

Lamellidens marginalis (Lamarck, 1819)

Taxonomic description- Shell oblong-ovate, twice as long as high, thin, smooth, somewhat inflated, inner surface of shell pearly and iridescent; periostracum blackish-brown and shinning; valves equilateral; umbones placed nearer to anterior end; dorsal margin behind the umbones almost straight, extends into a more or less well defined wing

expansion; anterior margin narrower than posterior margin, anterior end evenly rounded; ventral margin slightly contracted in the middle; right valve with hinge with two cardinals, upper one poorly developed, a single lateral and a trace of second one;
left valve with one cardinal and two curved lateral teeth; adductor impression and non-sinuate pallial line typical.
Lamellidens corrianus (Lea, 1834)

Taxonomic description- Shell narrowly elliptical, longer in proportions to height; valves equilateral, relatively thin; umbones slightly inflated; periostracum smooth, dark or greenish brown; anterior margin rounded, posterior margin more or less sub-angular; posterior wing expansion thin, ventral margin evenly curved; cardinal teeth thin, lamina like, two in each valve or one in left and two in right valve; lateral teeth elongated, thin, straight; nacre bluish white or pearly white and iridescent; adductor scars and pallial line fairly marked.

Parreysia caerulea (Lea, 1831)

Taxonomic description- Shell elongate, internally nacreous, sculpture restricted to the upper half of the valves in the adult, young shells with whole shell surface sculptured; posterior umbonal carina very distinct.

Land Snails
Key to families (land snails)

1. Shell non operculate, longer than broad, spire elongate ----------2
2. Shell non operculate, broader than long, spire depressed----------Ariophantidae
3. Shell usually imperforate or very narrowly perforate, spire longer than the last whorl ---------- Subulinidae
4. Shell perforate, spire equal or shorter than the last whorl ----------Cerastuidae

Class: Gastropoda
Subclass: Pulmonata
Superorder: Stylommatophora
Family: Ariophantidae
Ariophantidae is the largest family of Indian land pulmonates. The shells of this family are dextral or sinistral and their size varying from small to large with no operculum. They are usually depressedly globose and broader than high.

Macrochlamys indica (Godwin-Austen, 1883)

Taxonomic description- Shell perforate, depressed, smooth, polished throughout, translucent, pale brownish, striations not distinctly and coarse, all whorls have microscopic longitudinal impressed lines, striations slightly flexuous, not close together; spire low, conoid; suture slightly impressed; number of whorls five and half, slightly convex above, last whorl not descending, rounded at the periphery and moderately convex beneath; aperture slightly oblique and broadly lunate; peristome thin dorsally; columellar margin curved, oblique, quite vertical, carried forward and briefly reflected above.

Family: Subulinidae
Subulinidae is a family of most diverse terrestrial gastropods. The shells of this family are elongate, turreted to cylindrical and their size varying from small to medium. They are uniformly coloured, whorls are smooth or with indistinct sculpture on apical whorls and in sutural region on lower whorls.
Opeas gracile (Hutton, 1834)

Taxonomic description- Shell small to large, thin walled, turreted, uniformly dull pale brown colored; spire gradually tapering; apex rounded; body whorl conspicuous, equal to two preceding whorls; number of whorls 10; aperture semi-ovate, slightly narrowed above, longer than broad; columellar lip slightly reflected, almost straight, outer lip thin, sharp edged.
Zootecus insularis (Ehrenberg, 1831)
Taxonomic description- Shell pupiform, sub cylindrical, thin, corneous white; number of whorls 7, moderately convex; body whorl slightly bigger, little above the aperture; aperture semi-oval, pointed above; columellar margin strongly reflected, thickened, partially covering umbilicus; umbilicus narrow, sculptured with fine closely set sub ventral striae.

Family: Cerastuidae
Cerastuidae is a family of air-breathing land snails. The shells of this family are ovate or oblong with size varying from small to medium. They are narrowly perforate or deeply umbilicate with fine sculpture or coarse striae.

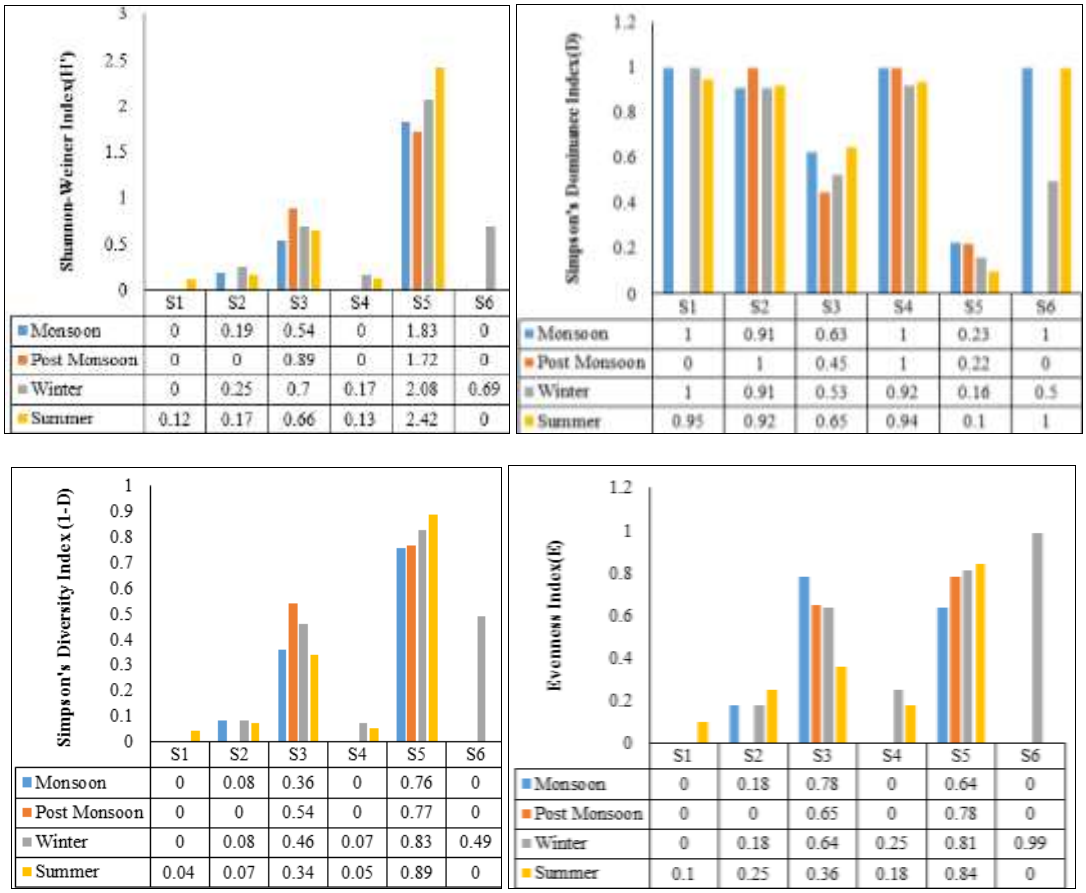
Rachis punctatus (Anton, 1839)

Taxonomic description- Shell ovately conical, smooth, glossy; number of whorls 6, feebly convex to almost flattened; spire elevated, cone like; apex obtuse; aperture slightly oblique, ovate; outer lip sharp, columellar lip reflected.

3.4 Seasonal variations in molluscan fauna diversity
Amongst the collected gastropod species *Physa acuta* was found ubiquitous and dominant species as well. In the hierarchy of dominance it was followed by *Melanoides tuberculata, Gabbia travancorica, Filopaludina bengalensis typica* and *Filopaludina bengalensis mandiensis*. The other species were found showing erratic occurrence and in lesser number. The species diversity, species richness and evenness of the collected molluscan fauna was found showing temporal or seasonal variations. (Figure 2).
The site S1 was found inhabited by only three molluscan species and their maximum richness was observed in summer season (3 Sp.) followed by monsoon while the winter season witnessed the presence of a single species i.e. *Physa acuta*. In the post monsoon season no molluscan shell was recovered from this site. The maximum abundance was also observed in summer season (237) followed by monsoon (22) and winter (20). Despite of the maximum abundance and higher species richness in summer season, the values of Simpson's Dominance Index (0.92) indicated the dominance of any one species.
The site S2 was found inhabited by only 4 species. The maximum species richness was observed in winter season (4 Sp.) followed by monsoon (3 Sp.), summer (2 Sp.) and post monsoon season (1 Sp.). Maximum abundance at this site was also observed in winter season (122) followed by monsoon (118), summer (77) and post monsoon season (1). In all seasons *P. acuta* was found as a dominating species.
From site S3, total 7 molluscan species were collected during

the entire study period of two years. The maximum species richness was observed in summer season (6 Sp.) followed by winter (4 Sp.), post monsoon (4 Sp.) and monsoon season (2 Sp.). Maximum abundance was also recorded in summer season (468), followed by winter (389), monsoon (73) and post monsoon (30). Despite of the maximum species richness and abundance in summer season the value of Simpson's Diversity Index (0.34) and H′ index (0.66) in summer indicated less diversity as compared to other seasons. This was due to the dominance shown by two species i.e. *P. acuta* and *M. tuberculata* while other species contributing towards the community diversity were represented in comparatively less number. Both the post monsoon and winter season witnessed equal number of species but the more abundance was observed in winter season in comparison to the post monsoon.

From site S4 three species i.e. *P. acuta*, *M. tuberculata* and *G. truncatula* were collected. *P. acuta* was found as a dominating species and was recovered in all four seasons. Only 2 specimens of *M. tuberculata were* collected in summer and winter season. A single shell of *G. truncatula* was found in summer season. *P. acuta* was found as a sole representative in monsoon and post monsoon season with 9 individuals in each season.



Shannon-Weiner Index(H')	S1	S2	S3	S4	S5	S6
Monsoon	0	0.19	0.54	0	1.83	0
Post Monsoon	0	0	0.89	0	1.72	0
Winter	0	0.25	0.7	0.17	2.08	0.69
Summer	0.12	0.17	0.66	0.13	2.42	0

Simpson's Dominance Index(D)	S1	S2	S3	S4	S5	S6
Monsoon	1	0.91	0.63	1	0.23	1
Post Monsoon	0	1	0.45	1	0.22	0
Winter	1	0.91	0.53	0.92	0.16	0.5
Summer	0.95	0.92	0.65	0.94	0.1	1

Simpson's Diversity Index (1-D)	S1	S2	S3	S4	S5	S6
Monsoon	0	0.08	0.36	0	0.76	0
Post Monsoon	0	0	0.54	0	0.77	0
Winter	0	0.08	0.46	0.07	0.83	0.49
Summer	0.04	0.07	0.34	0.05	0.89	0

Evenness Index(E)	S1	S2	S3	S4	S5	S6
Monsoon	0	0.18	0.78	0	0.64	0
Post Monsoon	0	0	0.65	0	0.78	0
Winter	0	0.18	0.64	0.25	0.81	0.99
Summer	0.1	0.25	0.36	0.18	0.84	0

Fig 2: Seasonal changes in the diversity of molluscan fauna

A total of 22 molluscan species were collected from the site S5. The summer and monsoon season were found supporting the maximum species richness (17 sp.) followed by winter (13 Sp.) and post monsoon (9 Sp.). Maximum abundance was observed during monsoon season (293) followed by summer (280), winter (239) and post monsoon (93). Though the monsoon season witnessed the maximum species richness and abundance still the values of Simpson's Diversity Index (0.76) and H′ index (1.83) indicated less diversity as compared to other seasons. This was due to dominance shown by a few species. The same was supported by the higher values of Simpson's Dominance Index (0.23) and lower values of Evenness Index (0.64) in the monsoon season. The other species were found in meager number hence were not contributing towards the species diversity. Similarly the summer season witnessed the maximum species diversity with highest values of Simpson's Diversity Index (0.89), H′ index (2.42) and Evenness Index (0.85). The post monsoon season was found least favorable for the molluscan species to flourish and diversify.

The site S6 was found having very poor molluscan fauna with only two representatives i.e. *Physa acuta* and *Galba truncatula*. The maximum species richness was observed in winter season along with higher value of the Evenness Index (0.99) indicating the presence and equal distribution of both species followed by summer and monsoon season representing only single species (*P. acuta*), while no shell was found in the samples collected during the post monsoon season. The maximum abundance was observed in summer season (154) followed by winter (28) and monsoon season (12).

4. Conclusion

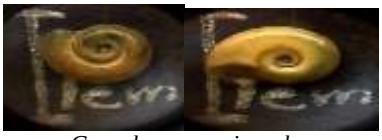
- The water bodies examined under the present study were found harboring low mollusc species richness except for the S5 site which witnessed the presence of maximum species.
- Non rainy seasons like summer and winter were found favoring maximum diversity of molluscan fauna in comparison to rainy seasons.

- The Ghaggar River (S1 and S2), the N-Choe (S3 and S4) and the Dhanas Lake (S6) witnessed the presence and dominance of an invasive species i.e. *Physa acuta* during the entire study period.
- Dominance of pollution tolerant species like *P. acuta* points towards the presence of organic effluents in the majority of water bodies under study.
- Presence of the species like *Gyraulus convexiusculus*, *Gabbia travancorica*, *Melanoides tuberculata*, *Radix acuminata*, *Radix luteola*, *Indoplanorbis exustus* and *Galba truncatula*, as suggested by literature, also fingers towards the potential threat of helminthal infections to the users of the water from the reservoirs under study.

Idiopoma dissimilis

Filopaludina bengalensis mandiensis

Filopaludina bengalensis typical



Gyraulus convexiusculus

Gyraulus euphraticus

Physa acuta

Indoplanorbis exustus

Macrochlamys indica

Thiara rudis

Lymnaea mimetica

Gabbia travancorica

Melanoides tuberculata

Radix persica

Radix acuminata

Radix biacuminata

Radix luteola

Galba truncatula

Rachis punctatus

Radix luteola ovalis

Opeas gracile

Zootecus insularis

Lamellidens marginalis

Lamellidens corrianus

Parreysia caerulea

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