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Seasonal dynamics of freshwater gastropods in central zone of Kashmir Valley, India

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ABSTRACT

The present study was carried out to study the prevalence and seasonal distribution of snail fauna in central zone of Kashmir valley. A total of 12,103 snails were collected during September 2017 to August 2018 and 10 snail species under 5 genera recorded were *Physa acuta, Lymnaea lagotis f. costulata*, *L. stagnalis*, *L. brevicauda*, *L. auricularia* var *obliquata*, *L. luteola f. typica*, *Gyraulus ladacensis*, *G. pankogensis*, *Bithynia troscheli* and *Indoplanorbis exustus*. Besides this, one unidentified snail was also reported. Species-wise overall prevalence was observed highest for *P. acuta* (18.65%), followed by *L. lagotis* (15.54%), *L. stagnalis* (13.31%), *G. ladacensis* (11.49%), *L. brevicauda* (10.19%), *B. troscheli* (8.00%), *L. auricularia* (6.94%), *I. exustus* (5.32%), *L. luteola* (5.15%), *G. pankogensis* (3.42%) and lowest for unidentified snail (1.94%). Prevalence of snails was found to be highest in summer (53.81%) followed by spring (29.76%), autumn (15.66%) and lowest in winter season (0.75%), the difference being statistically significant between seasons. Overall F% and RF% of snails was observed to be highest for *P. acuta* followed by *Lymnaea* spp. other than *L. stagnalis*, *Gyraulus* spp., *B. troscheli*, *I. exustus* and lowest for unidentified snail. Overall F% and RF% of snails was also observed highest in summer followed by spring, autumn and lowest in winter season. Based on RF%, all snails were found highly distributed, except for unidentified snail, which was found to be lightly distributed. The study concluded that *Physa* snails were found highly prevalent. Knowledge of the particular snail and cercariae released by them could be used to formulate control strategy to reduce the burden of trematode parasites in animals. Unidentified snail recorded in this study appears to be new species, which needs further detailed investigation.

Keywords: Central zone of Kashmir valley, Relative frequency, Seasonal dynamics, Snails

Fresh water snails are commonly found in marshes and swamp lands, permanent or temporary ponds, natural and man-made fresh water lakes, seasonal or permanent or slow flowing river streams, irrigation canals, rice fields and all other types of standing slow flowing or impounded water (Rai and Jauhari 2016, Wani *et al.* 2019, Latchumikanthan *et al*. 2019, Bulbul *et al*. 2020a, Nwoko *et al.* 2022). The distribution of fresh water snails account for the occurrence of different trematodes in different geographical regions as they act as intermediate hosts for digenetic trematode parasites (Devi *et al*. 2006, Jayawardena *et al*. 2010, Imani-Baran *et al*. 2013, Bauri *et al*. 2015, Dunghungzin and Chontananarth 2020, Bulbul *et al.* 2020b). In order to evolve a long-term strategic control measures against snail-borne parasitic diseases, it is necessary to know the distribution pattern of snail vectors. There has been well-documented information on snail vectors prevalent in various parts of the country (Deka 1999, Devi *et al*. 2006, Tigga *et al*. 2014, Soundararajan *et al*. 2018, Latchumikanthan *et al*. 2019). The canals, ponds, drains, paddy fields with irrigation channels, marshy lands and river Jhelum are favourable for the breeding of snail population in Kashmir valley (Dhar *et al*. 1985, Allaie *et al*. 2019, Wani *et al.* 2019). The abundance of infective snails also depends on the F% and RF% in a particular area (Bulbul *et al*. 2020c). With this background information in mind, the present study was undertaken to study the seasonal prevalence of various species of fresh water snails and determine their population density in terms of frequency and relative frequency per cent in Central Zone of Kashmir Valley.

MATERIALS AND METHODS

Location and geography of study area: Central Zone comprises of 3 districts, viz. Budgam, Ganderbal and Srinagar. Budgam district is situated at 75°E longitude and 34°N latitude and district Ganderbal is at 34.23°N latitude and 74.78°E longitude, while Srinagar district is situated at 34°5′23″N and 74°47′24″E. In Central Kashmir, summers

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are usually mild with good little rain, but relative humidity is generally high and nights are cool. The precipitation occurs throughout the year and no month is particularly dry. The hottest month is July (maximum temperature of 32°C and minimum temperature 6°C) and coldest months are December-January (max. tempt. 0°C and minimum tempt. -1.5°C).

Prevalence study

Collection of snails: A total of 12,103 snails were collected from different water bodies of each district in each season of the year to determine the seasonal prevalence of snails during September 2017 to August 2018. The snails brought to the laboratory in plastic bags/jars with little water from the place of collection were then washed with tap water to remove any extraneous material sticking to the shell. The prevalence of snails was calculated as per the method described by Devi (2001).

Identification of snails: Snails were identified based on the shell characteristics as described by Subba Rao (1989) and Brian Eversham (2013). Identification of representative specimens was confirmed from Zoological Survey of India, Kolkata (ZSI, Moll: I.R.No.107) and Department of Parasitology, College of Veterinary Sciences, Assam Agricultural University, Khanapara, Guwahati.

Population density of snails: One sq. m area was taken as a quadrate from different locations surveyed in each district to record the population density of snails. Species of snails that fell within the quadrate were counted. A total of 1200 (400 in each district) quadrants were analyzed among which 300 quadrants were investigated in each season to record seasonal density. Calculation for frequency per cent (F%) and relative frequency per cent (RF%) of snails was done using the formula described by Bulbul (2016).

Statistical analysis: The data obtained were analyzed by employing Z-test (Snedecor and Cochran 1994).

RESULTS AND DISCUSSION

Occurrence of 10 species under 5 genera and one unidentified snail recorded during the study were *P. acuta*, *L. lagotis*, *L. stagnalis*, *G. ladacensis*, *L. brevicauda*, *B. troscheli, L. auricularia*, *I. exustus*, *L. luteola*, *G. pankogensis* and unidentified snail (Fig. 1). From Kashmir valley, Dhar *et al*. (1985) reported *L. stagnalis*, *L. luteola*, *L. auricularia sensu stricto*, *Indoplanorbis exustus*, *Bithynia* spp., *Gyraulus compressus* and *Planorbis planorbis*; Dey and Mitra (2000) recorded *Planorbis rotundatus, Gyraulus euphraticus, Bithynia tentaculata kashmirensis, Hippeautis fontanus* and *Lymnaea lagotis*; Allaie *et al*. (2019) reported *L. auricularia*, *I. exustus*, *B. tentaculata* and *L. stagnalis*. Gupta *et al*. (1987) reported *I. exustus*, *L. luteola*, *L. acuminata* and *L. auricularia* from

Physa acuta | *Lymnaea lagotis* | *Lymnaea stagnalis* | *Lymnaea brevicauda*

Lymnaea auricularia | *Lymnaea luteola* | *Indoplanorbis exustus* | *Bithynia troscheli*

Gyraulus ladacensis | *Gyraulus pankogensis* | *Unidentified snail*

Fig. 1. Identified snail shells.

Table 1. Overall prevalence of snails in Central zone of Kashmir valley

Area screened	Snails collected	A	B	C	D	E	F	G	H	I	J	K
Budgam	3961 (32.72)^{A}	535 (13.50)^{A}	219 (5.52)^{BC}	605 (15.27)^{D}	410 (10.35)^{E}	258 (6.51)^{C}	212 (5.35)^{B}	323 (8.15)^{F}	735 (18.55)^{H}	445 (11.23)^{E}	141 (3.55)^{I}	78 (1.96)^{J}
Ganderbal	5152 (42.56)^{C}	712 (13.81)^{A}	280 (5.43)^{BC}	811 (15.74)^{D}	527 (10.22)^{E}	324 (6.28)^{C}	271 (5.26)^{B}	423 (8.21)^{F}	965 (18.73)^{H}	578 (11.21)^{E}	170 (3.29)^{I}	91 (1.76)^{J}
Srinagar	2990 (24.70)^{B}	364 (12.17)^{A}	125 (4.18)^{B}	466 (15.58)^{C}	297 (9.93)^{D}	259 (8.66)^{DE}	161 (5.38)^{F}	223 (7.45)^{E}	558 (18.66)^{G}	368 (12.30)^{A}	103 (3.44)^{B}	66 (2.20)^{H}
Total	12103	1611 (13.31)^{A}	624 (5.15)^{B}	1882 (15.54)^{C}	1234 (10.19)^{D}	841 (6.94)^{E}	644 (5.32)^{B}	969 (8.00)^{F}	2258 (18.65)^{H}	1391 (11.49)^{I}	414 (3.42)^{J}	235 (1.94)^{K}

Figures in the parenthesis indicate % prevalence. A= *L. stagnalis*; B= *L. luteola*; C= *L. lagotis*; D= *L. brevicauda*; E= *L. auricularia*; F= *I. exustus*; G= *B. troscheli*; H= *P. acuta*; I= *G. ladacensis*; J= *G. pankogensis*; K= Unidentified snail. Prevalence values of different snail types in a district and total along the row bearing different uppercase superscript differ significantly ($p<0.05$).

Haryana; Ngoen-klan *et al*. (2010) reported *Bithynia* spp., *Gyraulus* spp., *Indoplanorbis* spp. and *L. auricularia rubiginosa* snails from sewage treatment wetland waters in Combodia; Sharma *et al*. (2013) recorded *L. luteola*, *I. exustus*, *P. acuta* and *G. ladacensis* from Jammu; Poonam *et al*. (2018) reported two freshwater snails *G. ladacensis* and *I. exustus* from Nud pond, Samba, Jammu. Latchumikanthan *et al*. (2019) collected *I. exustus*, *Lymnaea luteola*, *Pila globose* and *Bellamyia* spp., from some parts of Union territory of Puducherry. Joseph *et al*. (2023) also collected snails belonging to 6 families like Planorbidae, Thiaridae, Lymnaeidae, Ampullariidae, Bithyniidae and Bivalviae from north-central Nigeria. Some of snail species are endemic to Kashmir Valley which may be due to the rigorous physical barriers. The presence of the malacofauna may be due to the favourable environmental conditions including abiotic and biotic components prevailing in the study areas.

The overall prevalence of different species of snails is depicted in Table 1. The difference was found to be statistically significant ($p<0.05$) between all snails except for *L. luteola* and *I. exustus* which differed non-significantly ($p>0.05$) with respect to each other. The species-wise prevalence of different snails recorded in the study are in close agreement with that of workers like Niaz *et al*. (2013) as regards prevalence of *P. acuta* (17.00%) and *Lymnaea* spp. (9.0%); Al-Waaly *et al*. (2014) as regards prevalence of *P. acuta* (14.00%) and *G. huwaizensis* (2.00%); Dunghungzin *et al*. (2017) found 8.05% prevalence of *L. auricularia* (8.05%) in Thailand; EL-Khayat *et al*. (2017) observed *P. acuta* was the most dominant snail (24.5%) among the collected snail species in some Egyptian water courses; Soundarajan *et al*. (2018) reported *Radix* snails (10.48%) and *I. exustus* (8.36%). Latchumikanthan *et al*. (2019) observed highest prevalence of *L. luteola* (41.68%) and lowest prevalence of *I. exustus* (9.33%) at Puducherry. Allaie *et al*. (2019) in Central Kashmir observed *L. auricularia* (44%) was the most prevalent fresh water snail followed by *I. exustus* (17.07%), *B. tentaculata* (15.60%) and *L. stagnalis* (9.07%) unlike our observation. The variation in prevalence of snails with respect to Allaie *et al*. (2019) could be due to less number of snail samples examined by the workers and in a particular season as it was preliminary study conducted in Central Kashmir, but the variation with respect to the other workers might be due to variations in the physical geography, land contours, soil composition, hydrography and climate of the region. *Physa acuta* was reported as the most prevalent snail, because of its shorter generation time which facilitates its colonization and expansion of the population at a higher rate than the other indigenous snails (De Kock and Wolmarans 2007).

Overall district-wise prevalence of snails: The highest prevalence was recorded in Ganderbal followed by Budgam and Srinagar district, the difference being statistically significant ($p<0.05$) among districts (Table 1). District wise variation in the overall prevalence of snails has also been reported by El-Kady *et al*. (2000) from Sinai Peninsula; Qureshi (2008) and Niaz *et al*. (2013) from Pakistan and Islam *et al*. (2015) from Bangladesh. The variation in the overall prevalence of snails in three districts might be due to variation in the number of snail samples collected from these districts, presence or absence of water reservoirs, canals, rivers and also due to the limnological properties of the water bodies prevailing in these districts. In all the three districts, the prevalence of individual snail species was more or less same as species wise overall prevalence of snails in the study areas.

Overall seasonal prevalence of snails: The highest prevalence was observed in summer followed by spring, autumn and lowest for winter season, the difference being statistically significant ($p<0.05$) between seasons (Table 2). Dhar *et al*. (1985) reported occurrence of *Lymnaea* snails throughout the year in Kashmir Valley. El-Kady *et al*. (2000) recorded highest number of snails in the months of April, May and June in Sinai Peninsula, while the lowest number was observed during January and February. Saddozai *et al*. (2013) reported gastropod population higher in summer and lowest in winter season in Manchar Lake Sindh, Pakistan while Afshan *et al*. (2013) found highest prevalence in summer as compared to winter season in Pothwar region, Pakistan. Niaz *et al*. (2013) recorded the highest prevalence of snails in summer season (42.1%) followed by winter (27.0%), autumn (20.2%) and lowest in spring season (10.50%) in Punjab region of

Table 2. Overall seasonal prevalence of snails in Central Zone of Kashmir Valley

Season	Snails collected	A	B	C	D	E	F	G	H	I	J	K
Autumn	1896	276	109	319	196	176	0	152	351	222	61	34
	(15.66)^{A}	(14.55)^{A}	(5.74)^{A}	(16.28)^{A}	(10.33)^{A}	(9.28)^{A}	(0.00)^{A}	(8.01)^{A}	(18.51)^{A}	(11.70)^{A}	(3.21)^{A}	(1.79)^{A}
Winter	91	27	0	24	0	0	0	0	40	0	0	0
	(0.75)^{B}	(29.67)^{B}	(0.00)^{B}	(26.37)^{B}	(0.00)^{B}	(0.00)^{B}	(0.00)^{A}	(0.00)^{B}	(43.95)^{B}	(0.00)^{B}	(0.00)^{B}	(0.00)^{B}
Spring	3603	459	189	547	365	249	233	292	662	411	128	68
	(29.76)^{C}	(12.73)^{A}	(5.24)^{A}	(15.18)^{A}	(10.13)^{A}	(6.91)^{C}	(6.46)^{B}	(8.10)^{A}	(18.37)^{A}	(11.40)^{A}	(3.55)^{A}	(1.88)^{C}
Summer	6513	849	326	992	673	416	411	525	1205	758	225	133
	(53.81)^{D}	(13.03)^{A}	(5.00)^{A}	(15.23)^{A}	(10.33)^{A}	(6.38)^{C}	(6.31)^{B}	(8.06)^{A}	(18.50)^{A}	(11.63)^{A}	(3.45)^{C}	(2.04)^{AD}
Total	12103	1611	624	1884	1234	841	644	969	2258	1391	414	235
		(13.31)^{a}	(5.15)^{b}	(15.54)^{c}	(10.19)^{d}	(6.94)^{e}	(5.32)^{b}	(8.00)^{f}	(18.65)^{h}	(11.49)^{i}	(3.42)^{j}	(1.94)^{k}

Figures in the parenthesis indicate % prevalence. A= *L. stagnalis*; B= *L. luteola*; C= *L. lagotis*; D= *L. brevicauda*; E= *L. auricularia*; F= *I. exustus*; G= *B. troscheli*; H= *P. acuta*; I= *G. ladacensis*; J= *G. pankogensis*; K= Unidentified snail. Prevalence values of a particular snail type in a particular column bearing different uppercase superscript and total along row bearing different small case superscript differ significantly.

Pakistan. Das *et al*. (2017) observed highest occurrence of snails in summer season followed by autumn, spring and winter season in Lakhimpur district of Assam. The variation in the results with respect to other workers might be because of variation in climatic factors and topography of the surveyed regions.

With respect to individual snail species, the prevalence of *L. stagnalis*, *L. lagotis* and *P. acuta* snails was recorded highest in winter followed by autumn, summer and spring season, while as *L. luteola*, *L. brevicauda*, *L. auricularia*, *G. ladacensis* snails showed highest prevalence in autumn followed by spring and summer season. Highest prevalence of *B. troscheli* and *G. pankogensis* snails was observed in spring followed by summer and autumn season. *I. exustus* was highly prevalent in spring followed by summer season, and it was not recorded in autumn season. The highest prevalence of unidentified snail was also observed in summer followed by spring and autumn (Table 2). The variation in the seasonal prevalence of different snail species recorded in this study is partially in contradiction with the findings of Gupta *et al*. (1987) who recorded highest prevalence of *L. Luteola* in spring and summer months. Nagare and Dummalod (2012) reported the highest abundance of *Lymnaea* snails in monsoon season which is different from the present findings. Dhar *et al*. (1985) recorded population of *L. auricularia* maximum during spring and autumn season in Nishat area of Srinagar, Kashmir. Niaz *et al*. (2013) observed prevalence of *I. exustus* highest in August (27.1%) followed by July (26.7%) and lowest in January and May (2.86%, 2.26%) in Punjab district of Pakistan. *L. luteola*, *L. brevicauda*, *L. auricularia*, *I. exustus*, *B. troscheli*, *G. ladacensis*, *G. pankogensis* and unidentified snails were not recorded in winter season. The higher prevalence of *L. stagnalis*, *L. lagotis* and *P. acuta* during winter season might be due to non-availability of other snails. The occurrence of *Lymnaea* snails round the year could also be attributed to the flooding of their habitats, seepage and/or overflow of canals during rainy season. This is supported by the findings of Gupta *et al*. (1987) who suggested that if the habitats of snail remain wet or flooded, then extreme temperatures (during summer and winter) had little ill effect on their persistence and perpetuation. *Lymnaea* snails also have explosive growth because of high reproductive rates under favourable conditions (Malone *et al*. 1984). So, small populations can quickly recover in number, as individuals are capable of self-fertilization (Dillon 2004). The rare occurrence of *I. exustus* in their natural habitat during autumn and winter clearly indicates that these snail species undergo hibernation from early autumn to early-spring. Budgam, Ganderbal and Srinagar districts revealed prevalence rates almost similar to that of overall prevalence of individual snails in Central Kashmir.

District-wise seasonal prevalence of snails: The study revealed highest prevalence in summer followed by spring, autumn and lowest for winter season in all districts. The difference was found statistically significant ($p<0.05$) between the seasons (Table 3).

Population density of snails: The population density of snails was calculated for *L. stagnalis*, *Lymnaea* spp. other than *L. stagnalis*, *I. exustus*, *B. troscheli*, *P. acuta*, *Gyraulus* spp. and unidentified snail.

Overall F% and RF% of snails: Overall F% and RF% was observed to be highest for *P. acuta* followed by *Lymnaea* spp. other than *L. stagnalis*, *Gyraulus* spp., *B. troscheli*, *I. exustus* and lowest for unidentified snail (Table 4). The difference of F% was found statistically significant ($p<0.05$) between *L. stagnalis* and unidentified snail; *Lymnaea* spp. other than *L. stagnalis* and unidentified snail; *I. exustus* and *P. acuta*; *B. troscheli* and *P. acuta*; *P. acuta*, *Gyraulus* spp. and unidentified snail and non-significant ($p>0.05$) between other snails. The difference of RF% was found statistically significant ($p<0.05$) between *L. stagnalis* and unidentified snail; *Lymnaea* spp. other than *L. stagnalis* and unidentified snail; *I. exustus* and *P. acuta*; *P. acuta*, *Gyraulus* spp. and unidentified snail; *B. troscheli* and *P. acuta* and non-significant ($p>0.05$) between other snails. Based on RF%, all snails were found highly distributed in these districts except for *B. troscheli* which was found to be moderately distributed in Budgam district and unidentified snail, which was found to be

Table 3. District-wise seasonal prevalence of snails in Central Zone of Kashmir Valley

District	Season	Snails collected	A	B	C	D	E	F	G	H	I	J	K
Budgam	Autumn	589 (14.86)^{A}	85 (14.43)^{A}	35 (5.94)^{A}	97 (16.97)^{A}	63 (11.03)^{A}	50 (8.48)^{A}	0 (0.00)^{A}	47 (7.97)^{A}	106 (17.99)^{A}	72 (12.22)^{A}	22 (3.73)^{A}	12 (2.03)^{A}
	Winter	35 (0.88)^{B}	10 (28.57)^{B}	0 (0.00)^{B}	10 (28.57)^{B}	0 (0.00)^{B}	0 (0.00)^{B}	0 (0.00)^{A}	0 (0.00)^{B}	15 (42.85)^{B}	0 (0.00)^{B}	0 (0.00)^{B}	0 (0.00)^{B}
	Spring	1129 (28.50)^{C}	148 (13.10)^{C}	62 (5.49)^{C}	171 (15.14)^{C}	116 (10.27)^{C}	77 (6.82)^{C}	70 (6.20)^{B}	92 (8.14)^{C}	206 (18.24) ^{C}	125 (11.07) ^{C}	40 (3.54)^{C}	22 (1.94)^{A}
	Summer	2208 (55.74)^{D}	292 (13.22)^{D}	122 (5.52)^{A}	327 (14.80)^{D}	231 (10.46)^{D}	131 (5.93)^{D}	142 (6.43)^{C}	184 (8.33)^{D}	408 (18.47)^{D}	248 (11.23) ^{D}	79 (3.57)^{D}	44 (1.99)^{C}
Total		3961 (32.72)^{A}	535 (13.50)a	219 (5.52)bc	605 (15.27)d	410 (10.35)e	258 (6.51)f	212 (5.35)b	323 (8.15)f	735 (18.55)h	445 (11.23)e	141 (3.55)i	78 (1.96)j
Ganderbal	Autumn	898 (17.43)^{A}	134 (14.92)^{A}	53 (5.90)^{A}	153 (17.03)^{A}	92 (10.24)^{A}	83 (9.24)^{A}	0 (0.00)^{A}	72 (8.01)^{A}	170 (18.93)^{A}	100 (11.13)^{A}	27 (3.00)^{A}	14 (1.56)^{A}
	Winter	45 (0.87)^{B}	15 (33.33)^{B}	0 (0.00)^{B}	10 (22.22)^{B}	0 (0.00)^{B}	0 (0.00)^{B}	0 (0.00)^{A}	0 (0.00)^{B}	20 (44.44)^{B}	0 (0.00)^{B}	0 (0.00)^{B}	0 (0.00)^{B}
	Spring	1531 (29.72)^{C}	203 (13.25)^{C}	82 (5.35)C	235 (15.34)^{C}	156 (10.18)^{C}	102 (6.66)^{C}	97 (6.33)^{B}	125 (8.16)^{C}	281 (18.35)^{C}	172 (11.23)^{C}	51 (3.33)^{C}	27 (1.76)^{C}
	Summer	2678 (51.98)^{D}	360 (13.44)^{D}	145 (5.41)^{D}	413 (15.42)^{D}	279 (10.41)^{D}	139 (5.19)^{D}	174 (6.49)^{C}	226 (8.43)^{D}	494 (18.44)^{D}	306 (11.42)^{D}	92 (3.43)^{D}	50 (2.01)^{D}
Total		5152 (42.56)^{B}	712 (13.81)a	280 (5.43)bc	811 (15.74)d	527 (10.22)e	324 (6.28)c	271 (5.26)b	423 (8.21)f	965 (18.73)h	578 (11.21)e	170 (3.29)i	91 (1.76)j
Srinagar	Autumn	409 (13.68)^{A}	57 (13.93)^{A}	21 (5.13)^{A}	69 (16.87)^{A}	41 (10.02)^{A}	43 (10.51)^{A}	0 (0.00)^{A}	33 (8.06)^{A}	75 (18.33)^{A}	50 (12.22)^{A}	12 (2.93)^{A}	8 (1.95)^{A}
	Winter	11 (0.37)^{B}	2 (18.18)^{B}	0 (0.00)^{B}	4 (36.36)^{B}	0 (0.00)^{A}	0 (0.00)^{B}	0 (0.00)^{A}	0 (0.00)^{B}	5 (45.45)^{B}	0 (0.00)^{B}	0 (0.00)^{B}	0 (0.00)^{B}
	Spring	943 (31.54)^{C}	108 (11.45)^{C}	45 (4.77) ^{C}	141 (14.95)^{C}	93 (9.86)^{C}	70 (7.42)^{C}	66 (6.99)^{B}	75 (7.95)^{C}	175 (18.55)^{C}	114 (12.08)^{C}	37 (3.92) ^{C}	19 (2.10)^{C}
	Summer	1627 (54.41)^{D}	197 (12.10)^{D}	59 (3.62) ^{C}	252 (15.48)^{D}	163 (10.01)^{D}	146 (8.97)^{D}	95 (5.83)^{C}	115 (7.06)^{D}	303 (18.62)^{D}	204 (12.53)^{D}	54 (3.31) ^{D}	39 (2.39)^{D}
Total		2990 (24.70)^{C}	364 (12.17)a	125 (4.18)b	466 (15.58)c	297 (9.93)d	259 (8.66)de	161 (5.38)f	223 (7.45)e	558 (18.66)g	368 (12.30)a	103 (3.44)b	66 (2.20)h
Grand Total		12103	1611 (13.31)^{a}	624 (5.15)^{b}	1882 (15.54)^{c}	1234 (10.19)d	841 (6.94)^{e}	644 (5.32)^{b}	969 (8.00)^{f}	2258 (18.65)^{h}	1391 (11.49)^{i}	414 (3.42)^{j}	235 (1.94)^{k}

Figures in the parenthesis indicate % prevalence. A= *L. stagnalis*; B= *L. luteola*; C= *L .lagotis*; D= *L. brevicauda*; E= *L. auricularia*; F= *I. exustus*; G= *B. troscheli*; H= *P. acuta*; I= *G. ladacensis*; J= *G. pankogensis*; K= Unidentified snail. Seasonal percentage values for a particular district in a particular column bearing different uppercase superscripts and total across rows bearing different smallcase superscripts differ significantly.

Table 4. Overall frequency per cent and relative frequency per cent of snails in Central Zone of Kashmir Valley

Area screened	A	B	F%	RF%	C	F%	RF%	D	F%	RF%	E	F%	RF%	F	F%	RF%	G	F%	RF%	H	F%	RF%	T. Freq
Budgam	400	116	29.00^{c}	15.32^{a}	152	38.00^{d}	20.07^{b}	93	23.25^{c}	12.28^{c}	76	19.00^{b}	10.03^{c}	169	42.25^{d}	22.32^{bc}	122	30.50^{bc}	16.11^{a}	29	7.25^{a}	3.83^{d}	189.25
Ganderbal	400	132	33.00^{cd}	15.36^{a}	159	39.75^{de}	18.51^{b}	106	26.5^{bc}	12.34^{c}	122	30.50^{b}	14.20^{d}	192	48.00^{e}	22.35^{ab}	112	28.00^{bc}	13.03^{ac}	36	9.00^{a}	4.19^{d}	214.75
Srinagar	400	122	30.50^{c}	17.11^{a}	128	32.00^{c}	17.95^{b}	93	23.25^{bc}	13.04^{a}	103	25.75^{bc}	14.44^{c}	145	36.25^{c}	20.33^{b}	96	24.00^{b}	13.46^{ac}	26	6.50^{a}	3.64^{d}	178.25
Total	1200	370	30.83	15.88^{bcd}	439	36.58^{bc}	18.85^{cd}	292	24.33^{ab}	12.53^{abc}	301	25.08^{ab}	12.92^{ab}	506	42.16^{c}	21.72^{d}	330	27.50^{b}	14.17^{bc}	91	7.58^{a}	3.90^{a}	194.06

F%, Frequency per cent; RF%, Relative frequency per cent. A, No. of quadrate studied; B, C, D, E, F, G, H, Quadrates +ve for *Lymnaea stagnalis*; *Lymnaea* spp. other than *L. stagnalis*; *I. exustus*; *B. troscheli*; *P. acuta*; *Gyraulus* spp.; unidentified snail, respectively. Percentage values of snails for a particular district across rows bearing different small case superscripts differ significantly (p<0.05).

lightly distributed in Budgam and Srinagar districts. The findings are in approximation with that of several workers like Kela *et al*. (1990) who reported the occurrence of snails ranging from 7.1% to 71.4% in Jos-Baunhi, Nigeria. Devi (2001) recorded 66.67% and 15.39% frequency and relative frequency of *I. exustus*, respectively in Deepor Beel, Assam, while Zukowski and Walker (2009) observed *P. acuta* as the most abundant snail in lower river Murray, Australia. Hussein *et al*. (2011) reported relative density of *L. natalensis* as high as 64 at Site I and as low as 0 at site V in Qena Governorate, Upper Egypt. Hanaa *et al*. (2017) also reported distribution of *P. acuta* snails ranging from 0.7 to 56.0% and *L. natalensis* ranging from 0.4 to 37% among 11 watercourses in Egypt. Bulbul *et al*. (2020c) reported F% (0 to 80.95%) and RF% (0 to 19.21%) for *I. exustus* in three districts of Assam which are higher as compared to our findings.

In Central Kashmir, usually mixed populations of snails occur at a particular location and it has been observed that juvenile *P. acuta* has been reported to grow more rapidly in water conditioned by *Lymnaea* snails suggesting an effect of pheromones or metabolites (Kawata and Ishigama 1992). *P. acuta* is a weedy species (Dillon 2000) and occurs in greatest abundance where there is a moderate amount of aquatic vegetation and organic debris (Smith 2001).

Overall seasonal F% and RF% of snails: Species-wise and overall seasonal F% and RF% of snails are depicted in Table 5. All the snails were found highly distributed in autumn, spring and summer seasons, while in winter *Lymnaea* and *Physa* snails were lightly distributed. In Ganderbal and Srinagar districts, unidentified snail showed similar frequency in spring and summer, followed by autumn season. Our findings corroborate with the findings of Pokhriyal *et al*. (1997) who observed the occurrence of *Lymnaea* snails throughout the year in Doon valley, Uttarakhand; Qureshi *et al*. (2015) reported significantly higher number of snails during summer and lower during winter season in Punjab, Pakistan; Bulbul (2016) reported frequency of *I. exustus* higher in monsoon followed by post-monsoon and pre-monsoon in Assam. The study is partially contradictory with Saddozai *et al*. (2013) who reported higher population of *Lymnaea* snails as compared to *P. acuta* and *G. eupharaticus* in Manchar lake, Sindh, Pakistan. Lacoursiere *et al*. (1975) and Vincent *et al*. (1982) suggested that gastropod variability is due to abiotic factors (depth, current and sediment) and Strzelec and Królczyk (2004) reported that many gastropod species are tolerant to most physicochemical water parameters and their occurrence is affected by the quality of bottom sediments and vegetation abundance.

District-wise seasonal F% and RF% of snails: Based on RF%, all the snails were highly distributed in autumn, spring and summer seasons, while in winter *Lymnaea* and *Physa* snails were found lightly distributed in Budgam district. Similar trend was found in Ganderbal district except for *Lymnaea stagnalis* which was found moderately distributed in winter. *Lymnaea* spp. other than *L. stagnalis*

Table 5. Overall seasonal frequency per cent and relative frequency per cent of snails in Central Zone of Kashmir Valley

Season	A	B	F%	RF%	C	F%	RF%	D	F%	RF%	E	F%	RF%	F	F%	RF%	G	F%	RF%	H	F%	RF%
Autumn	300	102	34.00^{a}	27.58^{a}	119	39.66^{b}	27.10^{b}	0	0.00	0.00	86	28.66^{c}	28.57^{c}	146	48.66^{d}	28.85^{d}	86	28.66^{bc}	26.06^{bc}	22	7.33^{d}	24.17^{d}
Winter	300	12	4.00^{a}	3.24^{a}	15	5.00^{a}	3.42^{a}	0	0.00	0.00	0	0.00	0.00	18	6.00^{b}	3.56^{b}	0	0.00	0.00	0	0.00	0.00
Spring	300	113	37.66^{a}	30.54^{a}	143	47.66^{b}	32.57^{b}	136	45.33^{b}	46.57^{c}	99	33.00^{c}	32.89^{b}	159	53.00^{d}	31.42^{a}	112	37.33^{bc}	33.94^{b}	33	11.00^{e}	36.27^{d}
Summer	300	143	47.66^{a}	38.64^{a}	162	54.00^{b}	36.91^{a}	156	52.00^{b}	52.43^{b}	116	38.66^{a}	38.53^{c}	183	61.00^{c}	36.17^{a}	132	44.00^{d}	40.00^{d}	36	12.00^{e}	39.56^{c}
Total	1200		123.32	100		146.32	100		97.33	100		100.32	100		168.66	100		109.99	100		30.33	100

F%, Frequency per cent; RF%, Relative frequency per cent. A, No. of quadrate studied; B, C, D, E, F, G, H, Quadrates +ve for *Lymnaea stagnalis*; *Lymnaea* spp. other than *L. stagnalis*; *I. exustus*; *B. troscheli*; *P. acuta*; *Gyraulus* spp.; unidentified snail, respectively. Percentage values of snails for a particular season across rows bearing different small case superscripts differ significantly ($p<0.05$).

and *Physa acuta* were found lightly distributed. In Srinagar district, *Physa acuta* was found to be moderately distributed in winter while *Lymnaea stagnalis* and *Lymnaea* spp. other than *L. stagnalis* which were found lightly distributed. In all the three districts, the seasonal F% and RF% of all the snails was recorded highest in summer followed by spring, autumn and lowest in winter season. Lower frequency of snails in autumn and winter was due to low temperature prevailing during these seasons and water level during autumn season recedes, leaving paddy fields, most of marshy areas, lakes, ponds dry, which results in the mortality of snails, thereby decreasing the population of snails.

The present study represents the first detailed study on snail fauna prevalent in Kashmir Valley. Eleven different species of freshwater snails were recorded in the region and based on their RF% they were found to be highly distributed in the region. Most of the snails undergo hibernation during the winter season except *Lymnaea* and *Physa* snails. One of the interesting finding was that *Physa* snails were found highly prevalent as compared to other parts of India. Density of snail in a particular area could give us an indication about the intensity of trematodal infections prevalent which could be used to formulate control strategy to reduce the burden of trematode parasites in animals. Besides this, mapping of snail infested areas could help in formulating grazing strategies so as to limit access of trematode parasites by animals. Unidentified snail recorded in this appears to be new species, which needs further characterization by molecular methods.

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