Spatial and temporal variation in the diversity of malacofauna from Aripal stream of Kashmir Himalaya, India

Zahoor Ahmad Mir 1,2 & Yahya Bakhtiyar 2

1,2 Fish Biology and Limnology Research Laboratory, Department of Zoology, University of Kashmir, Srinagar, Jammu & Kashmir 190006, India.
1 mirzahoor88@gmail.com, 2 yahya.bakhtiyar@gmail.com (corresponding author)

Abstract: This paper presents the spatial and temporal variation in the diversity of malacofauna in relation to the water chemistry of the Aripal stream of Kashmir Himalaya. A total of 12 species were reported which belong to four families, Lymnaeidae, Physidae, Planorbidae, and Bithyniidae from class Gastropoda, and two families, Cyrenidae and Pisidiidae from class Bivalvia. The family Planorbidae contributed 34% to the total annual molluscan population followed by Lymnaeidae (28%) and Bithyniidae (18%). During the collection, Gyraulus sp., Planorbis sp., and Bithynia tentaculata were prevalent at all sites, with predominance of Bithynia tentaculata. Species richness and abundance were observed maximum at site A3 (down-stream) and minimum at site A1 (up-stream) while in the case of temporal variation, species richness and abundance were maximum in summer and minimum in winter. Shannon-Wiener index, Simpson index, Margalef index, and Pielou evenness index were used to calculate the diversity, dominance, richness, and evenness of molluscan species, respectively. Physico-chemical parameters revealed a non-significant spatial variation (P >0.05) except pH, total hardness, and alkalinity while a significant temporal variation (P <0.05) was observed in the physico-chemical parameters except dissolved oxygen. A significant positive correlation was seen between the molluscan species and total hardness. In the present study, the stone mining, channel morphology of stream, habitat heterogeneity, and physico-chemical parameters were also found to promote the spatial and temporal diversity of malacofauna.

Keywords: Abundance, classification, distribution, freshwater ecosystems, macrobenthic invertebrates, molluscs, Pearson’s correlation, physico-chemical parameters, richness.
INTRODUCTION

Molluscs serve as sources of food for fishes, birds and mammals (Wosu 2003). Molluscs also act as intermediate hosts to helminth parasites that cause diseases such as schistosomiasis and fascioliasis in humans and livestock (Mostafa 2009; Alhassan 2020; Silva et al. 2020). Freshwater molluscs, being detritus feeders, play a significant role in improving water quality (Martin 1991; Reddy 1995). Freshwater bodies are inhabited by two classes of molluscs: Gastropoda and Bivalvia, with the Gastropoda forming the largest group (Lydeard et al. 2004). Both gastropods and bivalves are diverse in aquatic ecosystems such as lakes, ponds, wetlands, springs, streams, and rivers, which act as models for ecological studies (APHA 1998). Ecological parameters like temperature, nature of substratum, type of vegetation, and water chemistry play significant role in the occurrence, distribution, and density of freshwater molluscs (Bournard et al. 1987; Boulton & lake 1992; Linke et al. 1999). Temperature has a major impact on the seasonal distribution and abundance of freshwater molluscs (Biggs et al. 1990). Bottom substrate such as boulders, cobbles, pebbles, gravel, and sand provide a suitable habitat for the colonization and establishment of molluscs in streams (Hynes 1970; Habib & Yousuf 2012). Growth of vegetation such as macrophytes and periphyton along and within the stream increases the density, distribution, and diversity of molluscs (Nelson et al. 1990; Bilby & Ward 1991; Ghani et al. 2017). Water chemistry parameters (viz., pH, alkalinity, hardness) influence the abundance and richness of molluscs (Peeters & Gardeniers 1998). The spatial and temporal variation in both biotic and abiotic parameters change the adaptation strategies along with the composition, distribution, and diversity of mollusc communities (Rosillon 1987; Poff & Ward 1989). The freshwater molluscs are facing threats from various sources such as water pollution, habitat destruction through dams and channelization, and climate change (Peeters & Gardeniers 1998; Primack 2002). The studies on Indian Himalayan malaco fauna is meager compared to other parts of India (Blanford & Godwin-Austen 1908; Rao 1993; Aravind et al. 2010; Sharma et al. 2010) and in Kashmir Himalaya, a well-documented work has been carried out on the diversity of benthic molluscan fauna (Qadri et al. 1981; Dhar et al. 1985; Pandit et al. 2002; Yousuf et al. 2006; Bhat & Pandit 2010; Habib & Yousuf 2014; Allaie et al. 2019). Despite the work carried out in the field of limnology, there is still a lack of knowledge and fragmentary information regarding habitat heterogeneity and changing riparian land use patterns along the hill streams. These aspects have a profound impact on the occurrence, abundance, and richness of benthic fauna and have been considered during the present study on the spatial and temporal variation in the diversity of malacofauna from the Aripal stream of Tral, Kashmir Himalaya.

MATERIALS AND METHODS

Description of the study area

The present study has been carried out from the Aripal stream, located in the Tral town, between geographic coordinates 33.93°N and 75.10°E with an altitude of 1,662 m in the district Pulwama, Kashmir valley. The stream originates in the northern ridge of Greater Himalaya and forms one of the important tributaries of the Jhelum river in the district. The town is situated 11 km away from NH 44 Awantipora and nearly about 40 km from Srinagar city. The Aripal watershed covers an area of 380 km² in the sub-district and provides various ecosystem services such as a source of drinking water and irrigation for horticulture and agriculture purposes and also forms an opportunity for trout culture in the area. The stream forms an important reservoir of construction materials such as boulders, cobbles, pebbles, gravel, and sand, which boost the rural economy (Mir & Saleem 2016). During the survey, three sites were selected from the stream, on the basis of distance, altitudinal distribution, riparian land-use types, and stream heterogeneity. The sites were marked as site A1 at Aripal (up-stream), 34.01°N & 75.04°E, 1,902 m, site A2 at Chandrigam (mid-stream), 33.55°N & 75.05°E, 1,607 m, and site A3 at Kadelbal (down-stream), 33.53°N & 75.02°E, 1,583 m (Image 1). The geographical representation of the Aripal watershed along with sampling sites was created through Arc-GIS software (Figure 1).

Sampling, processing, and identification

Sampling was carried out on monthly basis from June 2018 to May 2019. The molluscan samples were collected by using standard bottom samplers (EU-WFD implemented) Surber net and D-net (HYDRO-BIOS) with 0.9 m² area and 0.5 mm mesh size (Rosenberg & Resh 1993; Barbour et al. 1999; Hayslip & Gretchen 2007). Wader and synthetic rubber gloves were used during wading in each sampling reach. A systematic method was followed to cover the different microhabitats in each sampling site (Peck et al. 2002). A standard operating
**Image 1.** Sample collection sites of Aripal stream with habitat heterogeneity. © Zahoor Ahmad Mir

**Figure 1.** Geographical representation of sampling sites of Aripal stream, Tral, Kashmir Himalaya.
method in benthic macroinvertebrate sampling, developed by Moulant et al. (2000) and Carter & Resh (2001) was followed for filtration, sieving, removing, and sorting of molluscs and extraneous material from the sample. During processing, samples were fixed with 4% formalin and preserved with 70% ethanol. The identification was done with the help of dissecting stereo zoom microscope (Magnus MS 24) with Magcam DC 10 camera following taxonomic keys (Edmondson 1959; Rao 1989; Ramakrishna & Dey 2007).

Physico-chemical parameters
The physico-chemical parameters of water, viz., dissolved oxygen (DO), alkalinity (Alk), total hardness (TH), air temperature (AT), water temperature (WT), pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured by following standard methods (APHA 1998).

Statistical analysis
Statistical analysis of data was performed by using MS excel 2016, SPSS 20, and Past 4 software. Shannon-Wiener index (1949), Simpson dominance index (1949), Margalef index (1958) and Pielou evenness index (1966) were used to calculate the diversity, dominance, richness, and evenness of molluscan species with the use of Past 4 software. Spatial and temporal data of physico-chemical parameters were subjected for one-way ANOVA followed by Duncan’s multiple range test and the relationship with molluscan species was determined through two-tailed Pearson’s correlation with the help of SPSS 20 software.

RESULTS

Molluscan diversity
During the present study, 1,509 individuals were collected from three different sites of the Aripal stream throughout the year. A total of 12 species were reported from six families and two classes. Gastropoda represented 10 species that belong to four families, Lymnaeidae, Physidae, Planorbidae, and Bithyniidae while the class Bivalvia was represented by four families, Lymnaeidae, Physidae, Planorbidae, and Gastropoda represented 10 species that belong to two classes. The Bivalvia species were reported from six families and two classes.

The class Gastropoda and Bivalvia contributed 82% and 18% to the total annual molluscan population (Figure 2). The family Planorbidae contributed 34% followed by Lymnaeidae (28%), Bithyniidae (18%), Cyrenidae (11%), Pisidiidae (7%), and Physidae (2%) to the total annual molluscan population (Figure 3). The species Bithynia tentaculata contributed 18% followed by Gyraulus sp. (16%), Pseudosuccinea columella (12%), Radix auricularia (10%), Corbicula cashmiriensis (10%), Planorbis sp. (8%), Indoplanorbis exustus (7%), Pseudosuccinea columella, Raciesina luteola, Corbicula cashmiriensis and Pisidium casertanum were reported from site A2 and site A3 of the stream (Table 2).

During the study, a total of eight physico-chemical parameters were recorded for one-way ANOVA followed by Duncan’s multiple range test and the relationship with molluscan species was determined through two-tailed Pearson’s correlation with the help of SPSS 20 software.

During the collection, Gyraulus sp., Planorbid sp., and Bithynia tentaculata were present at all the sites, while Physella acuta was observed only at site A2 (mid-stream) and Lymnaea stagnalis, Segmentina sp. and Indoplanorbis exustus were present only at site A3 (down-stream). Radix auricularia, Pseudosuccinea columella, Raciesina luteola, Corbicula cashmiriensis and Pisidium casertanum were reported from site A2 and site A3 of the stream (Table 2).

The diversity was observed highest at site A3 (2.25) and lowest at site A1 (1.04), dominance was recorded highest at site A1 (0.37) and lowest at site A3 (0.12), species richness was observed highest at site A3 (1.47) while lowest at site A1 (0.41) and evenness was recorded highest at sites A1 & A3 (0.94) while lowest at site A2 (0.78) (Figure 5).

In the temporal variation of malacoфаuna, the diversity was observed highest in summer season (2.33) while lowest in winter season (2.06), dominance was recorded maximum in winter season (0.14) while minimum in summer season (0.11), species richness was observed maximum in summer season (1.74) while minimum in winter season (1.45) and evenness was recorded maximum in spring season (0.89) while minimum in summer season (0.86) (Figure 6).

Physico-chemical parameters
During the study, a total of eight physico-chemical parameters were recorded. The air temperature (AT) ranged from 4–25 °C with a mean value of 16.3±7.5 °C, water temperature (WT) ranged from 7.67–19 °C with mean value of 13.2±3.7 °C, dissolved oxygen (DO) ranged from 8.13–14.33 mg/L with mean value of 11.1±1.8 mg/L, pH ranged from 7.33–8.47 with mean value of 7.8±0.4, electrical conductivity (EC) ranged from 126.67–368.67 µS cm⁻¹ with mean value of 256.3±84.4 µS cm⁻¹, total dissolved solids (TDS) ranged from 62–184.33 mg/L with mean value of 121.6±42.1 mg/L, total hardness
Diversity of malacofauna from Aripal Stream of Kashmir Himalaya

Table 1. The systematic list of malacofauna from Aripal stream.

| Phylum   | Class   | Order   | Family       | Genus/Species                   |
|----------|---------|---------|--------------|---------------------------------|
| Mollusca | Gastropoda | Basommatophora | Lymnaeidae | Radix auricularia |
|          |         |         |             | Lymnaea stagnalis           |
|          |         |         |             | Pseudosuccinea columella     |
|          |         |         |             | Racesina luteola             |
|          |         |         | Physidae    | Physella acuta               |
|          |         |         | Planorbidae | Segmentina sp.               |
|          |         |         |             | Indoplanorbis exustus       |
|          |         |         |             | Gyraulus sp.                 |
|          |         |         |             | Planorbis sp.                |
|          | Mesogastropoda | Bithyniidae |             | Bithynia tentaculata         |
|          | Bivalvia | Venerida | Cyrenidae    | Corbicula cashmiriensis      |
|          |         |         | Pisidiidae  | Pisidium casertanum          |

Image 2. Collected and identified molluscan species from Aripal stream: A—Radix auricularia | B—Lymnaea stagnalis | C—Pseudosuccinea columella | D—Racesina luteola | E—Physella acuta | F—Segmentina sp. | G—Indoplanorbis exustus | H—Gyraulus sp. | I—Planorbis sp. | J—Bithynia tentaculata | K—Corbicula cashmiriensis | L—Pisidium casertanum. © Zahoor Ahmad Mir
The descriptive analysis in the physicochemical parameters of the Aripal stream on spatial and seasonal scale is presented in the Table 4 & 5, respectively. A relationship between the molluscan species and physico-chemical parameters of the Aripal stream showed a significantly positive correlation with the total hardness. The Radix auricularia, Racesina luteola, Gyraulus sp., Planorbis sp., and Corbicula cashmiirienses revealed a very significant positive correlation (P <0.01) with total hardness while the Lymnaea stagnalis, Pseudosuccinea columella, Segmentina sp., Indoplanorbis exustus, and Pisidium casertanum showed a significant positive correlation (P <0.05) with water temperature and pH. The Planorbis sp. showed a very significant positive correlation (P <0.01) with air temperature and water temperature. The Bithynia tentaculata revealed a very significant positive correlation (P <0.01) with air temperature and water temperature while a negative significant correlation (P <0.05) with alkalinity (Table 6).

**DISCUSSION**

The ecology of a place and the seasons of a year play an important role in the distribution and abundance of organisms. During the present study, the distribution and abundance of freshwater molluscs were monitored in the Aripal stream of Kashmir Himalaya, where 12 species were reported which belong to six families and two classes. Out of 12 species, 10 species belong to class Gastropoda, and the remaining two species belong to class Bivalvia. The family Planorbidae showed a high contribution to the total molluscs at all the selected sites of the stream, followed by the Lymnaeidae and Bithynidae. Sharma et al. (2010) observed similar results regarding the diversity and distribution of
Diversity of malacofauna from Aripal Stream of Kashmir Himalaya

Mir & Bakhtiyar

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2022 | 14(3): 20747–20757

Table 4. Spatial variation in the physico-chemical parameters from Aripal stream.

| Parameters   | Site A1       | Site A2       | Site A3       |
|--------------|---------------|---------------|---------------|
| AT (°C)      | 15.4±6.5°     | 16.5±8°       | 16.8±8.1°     |
| WT (°C)      | 12.4±2.8°     | 14.2±4.7°     | 13.1±3.5°     |
| DO (mg/L)    | 10.7±1.2°     | 11.6±2.1°     | 10.8±2.2°     |
| pH           | 7.6±0.3°      | 7.9±0.4°      | 7.9±0.3°      |
| EC (µs cm⁻¹) | 226±90.3°     | 258.9±80.7°   | 283.9±82.2°   |
| TDS (mg/L)   | 108.4±44.8°   | 122.8±39.8°   | 133.8±41.5°   |
| TH (mg/L)    | 78.3±32.8°    | 94.6±29°      | 111.5±36.9°   |
| Alk (mg/L)   | 80.9±20.1°    | 92.1±19.4°    | 109.5±25°     |

Parameter sharing the same superscript among the sites are nonsignificant (P >0.05); one-way ANOVA applied followed by Duncan’s multiple range test.

Table 5. Seasonal variation in the physico-chemical parameters from Aripal stream.

| Parameters   | Summer | Autumn | Winter | Spring |
|--------------|--------|--------|--------|--------|
| AT (°C)      | 24.1±1.3° | 17.4±5° | 6.7±2.5° | 16.9±4° |
| WT (°C)      | 17.4±2.9° | 12.8±3.3° | 9.7±1.5° | 13±2° |
| DO (mg/L)    | 10.2±1.1° | 11.1±1.9° | 11.7±1.8° | 11.2±1.6° |
| pH           | 7.7±0.3° | 8±0.6° | 7.6±0.2° | 7.9±0.1° |
| EC (µs cm⁻¹) | 183.8±68.5° | 315.7±55.6° | 335.1±32° | 190.6±38.2° |
| TDS (mg/L)   | 87.7±31.6° | 156.8±30° | 150.1±24.8° | 92±26.4° |
| TH (mg/L)    | 108.1±51.1° | 90±19.1° | 71.8±24.4° | 109.3±26.6° |
| Alk (mg/L)   | 78±17.7° | 87.6±17.7° | 120±125.9° | 91.8±12.1° |

Parameter sharing the same superscript among the seasons are nonsignificant (P >0.05); one way ANOVA applied followed by Duncan’s multiple range test.

Figure 4. The annual percent contribution of different species to the total molluscan population.

Table 6. Correlation between the molluscan species and physico-chemical parameters from Aripal stream.

| Malacoofauna          | AT     | WT     | DO     | pH     | EC     | TDS    | TH     | Alk    |
|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Radix auricularia     | 0.48   | 0.5    | -0.28  | 0.4    | -0.06  | -0.06  | 0.82** | 0.15   |
| Lymnaea stagnalis     | 0.16   | 0.06   | -0.28  | 0.29   | 0.08   | 0.09   | 0.68*  | 0.39   |
| Pseudosuccinea columella | 0.48   | 0.61*  | -0.01  | 0.60*  | 0.01   | 0.02   | 0.65*  | 0.14   |
| Racesina luteola      | 0.55   | 0.56   | -0.20  | 0.46   | -0.10  | -0.05  | 0.81** | -0.01  |
| Physella acuta        | 0.13   | 0.23   | -0.51  | 0.43   | 0.07   | 0.13   | 0.06   | -0.19  |
| Segmentino sp.        | 0.20   | 0.13   | -0.32  | 0.16   | 0.18   | 0.14   | 0.62*  | 0.38   |
| Indoplanorbis exustus | 0.31   | 0.20   | -0.37  | 0.24   | 0.11   | 0.10   | 0.68*  | 0.28   |
| Gyraulus sp.          | 0.42   | 0.33   | -0.38  | 0.24   | -0.06  | -0.07  | 0.78** | 0.18   |
| Planorbis sp.         | 0.72** | 0.74** | -0.33  | 0.43   | -0.26  | -0.24  | 0.79** | -0.18  |
| Bithynia tentaculata  | 0.90** | 0.95** | -0.38  | 0.24   | -0.57  | -0.50  | 0.50   | -0.70* |
| Corbicula现金riensis   | 0.23   | 0.29   | -0.02  | 0.50   | 0.12   | 0.11   | 0.73** | 0.43   |
| Pisidium casertanum    | 0.46   | 0.61*  | 0.03   | 0.61*  | -0.11  | -0.08  | 0.67*  | 0.07   |

'**' significant correlation at P <0.05; '***' highly significant correlation at P <0.01; two-tailed Pearson’s coefficient of correlation (r) applied.
Gastropoda. Hora et al. (1955) observed the prevalence of *Gyraulus* sp., *Indoplanorbis exustus*, and *Valvata* sp. in the Kashmir valley. However, in our case, *Gyraulus* sp., *Planorbis* sp., and *Bithynia tentaculata* were recorded from all the sites which may be attributed to the availability of food and shelter in the form of leaf litter, aquatic macrophytes, periphyton, and organic-rich bottom sediments of different sites. The high prevalence of *Bithynia tentaculata* in the stream may be due to the better capability of utilizing the organic matter available in the bottom substrate. The presence of *Lymnaea stagnalis*, *Segmentina* sp., and *Indoplanorbis exustus* with the increase in electrical conductivity and total dissolved solids at site A3 may act as bioindicator of pollution. Wagh et al. (2019) noticed similar results with respect to freshwater molluscs in the Amravati district of Maharashtra, India. The selected sites along the stream face various types of disturbances. The site A1 is disturbed due to stone mining, floods, and land-use changes, site A2 is disturbed mainly from washing clothes and domestic sewage and site A3 receives the agricultural runoff from surrounding agricultural land. The presence of few species at site A1 (up-stream) may be the key cause of stone mining, occasionally torrential flow during floods, and change in land-use patterns which may cause habitat instability and result negative impacts upon the molluscan fauna. However, the species number increased abruptly towards the downstream which may be attributed to the reduction in the stream slope, low velocity, stability of bottom substrate, the inflow of nutrients from surrounding agricultural land, and sedimentation of fine organic matter. Further high diversity, richness, and evenness were observed at site A3 (down-stream) and low values at site A1 (up-stream). The high diversity, richness, and evenness in the downstream may reflect the stability of bottom substrate due to downward serpentine flow, formation of pool-rich stretches, and presence of different microhabitats by the introduction of woody debris and growth of periphyton and submerged macrophytes. The findings are validated by Strzelec & Krolczyk (2004) who reported that sandy bottom, vegetation, and organic sedimentation are the most suitable substrate for rich molluscan fauna. The richness of the molluscan species at site A2 and site A3 may also be attributed to the combined effect of higher values of alkalinity, pH, total hardness, and total dissolved solids. During the present study, majority of molluscan species showed a significant positive
correlation with physico-chemical parameters. Many workers have reported a positive correlation between these parameters and mollusca (Malhotra et al. 1996). The dissolved oxygen showed spatially and temporally non-significant variation in the stream and also revealed a non-significant correlation with molluscan species. A similar trend was observed in earlier studies (Sharma 1986). In the temporal variation of mollusca, the species diversity and richness were observed maximum in the summer season while minimum in the winter season. This may be related to the two important parameters, viz., temperature and organic matter. The increase in the temperature during the summer season may activate the decomposition of organic matter suspended in the bottom substrate and may accelerate its conversion into inorganic nutrients. This process may promote the growth and structure of periphyton and macrophytes which form the suitable substrate for malacofauna. The statement is related to the findings of various other authors as well (Dutta & Malhotra 1986; Malhotra et al. 1996; Bath et al. 1999). The present study presents the spatial and temporal diversity patterns of malacofauna in the Aripal stream of Kashmir Himalaya. Mollusca as one of the components of macrobenthic invertebrates play role in the regulation of suspended organic matter within the bottom substrate of streams. The study emphasizes the need for the conservation of streams and their role in shaping the occurrence, distribution, abundance, and richness of malacofauna. Streams as freshwater ecosystems provide habitat for diverse flora and fauna and thus form an important model for ecological studies.

REFERENCES

Alhassan, A., A. Abidemi, I. Gadzama, R. Shaaba & Y. Wada (2020). Distribution and Diversity of Freshwater Snails of Public Health Importance in Kubanni Reservoir and Weir/Sediment Trap, Zaria, Nigeria. Journal of Environmental and Occupational Health 10(1): 1–9.

Allaie, I.M., R.A. Shahardar, A. Prasad, S.R. Tramboo, Z.A. Wani & S.S. Kubra (2019). Prevalence of snails in central Kashmir, India 7(3): 1018–1020.

American Public Health Association APHA (1998). Standard methods for the examination of water and wastewater. Washington, DC, 20 pp.

Aravind, N.A., K.P. Rajasekhar & N.A. Madhyastha (2010). A review of ecological studies on patterns and processes of distribution of land snails of the Western Ghats, India. Proceeding of World
Diversity of malacofauna from Aripal Stream of Kashmir Himalaya

Diversity of malacofauna from Aripal Stream of Kashmir Himalaya Mir & Bakhtiyar

Quantitative analysis of Edmondson, W.T. (1959).

After site selection and before data

Habib, S. & A.R. Yousuf (2012).

Dhar, D.N., G.C. Bansal & R.L. Sharma (1985).

Dutta, S.P. S. & Y. R. Malhotra (1986).

Bournard, M., H. Tachet, A.L. Roux & Y. Auda (1987).

Hynes, H.B.N. (1970).

Barbour, M.T., J. Gerritsen, B.D. Snyder & J.B. Stibring (1999). Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. 2nd Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency. Office of Water. Washington, District of Columbia, U.S.A. 339 pp.

Bath, K.S., H. Kaur & S.S. Dhallon (1999). Correlation of Molluscs with Physico-chemical factors at Harke Reservoir (Punjab). Indian Journal of Environmental Sciences 3: 159–163.

Bhat, S. & A.K. Pandit (2010). Ecological study of Benthic communities in Three Limnocrene freshwater springs in Kashmir Himalaya. Journal of Natural Sciences and Mathematics 3(2): 89–96.

Biggs, B.J., J.G. Jowett, J.M. Quinn, C.W. Hickey, R.J. Davies-Colley & M. Close (1990). Ecological characterization, classification, and modeling of New Zealand rivers: An introduction and synthesis. New Zealand Journal of Marine and Freshwater Research 24: 277–304.

Bilby, R.E. & J.W. Ward (1991). Characteristics and function of large woody debris in streams draining old growth, clear cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48: 2499–2508.

Blanford, W.T. & H.H. Godin-Austen (1908). The fauna of British India, including Ceylon and Burma, Mollusca I: Testacellidae and Zonitidae. Taylor & Francis, London 311 pp.

Boulton, A.J. & P.S. Lake (1992). The ecology of two intermittent streams in Victoria, Australia III. Temporal changes in faunivorous composition. Freshwater Biology 27: 123–136.

Bournard, M., H. Tachet, A.L. Roux & Y. Auda (1987). The effects of seasonal and hydrological influences on the macroinvertebrates of the Rhone River, France 1. Methodological aspects. Archives of Hydrobiology 109: 287–304.

Carter, J.L & Rlesh V.H. (2001). After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. Journal of North American Benthological Society 20: 658–682.

Dhar, D.N., G.C. Bansal & R.L. Sharma (1985). Studies on the aquatic snails of Kashmir Valley with particular reference to Lymnaea auricularia sensu stricto. Indian Journal of Parasitology 9: 241–44.

Dutta, S.P. & Y.R. Malhotra (1986). Seasonal variations in the macro-benthic fauna of Gadigarh stream (Miran Sahib), Jammu. Indian Journal of Ecology 13: 138–145.

Edmondson, W.T. (1959). Freshwater Biology. John Wiley and Sons Inc., New York, London.

Ghani, A., N. Afsar & S. Rahman (2017). Quantitative assessment of macrobenthic molluscan populations inhabiting Bandri area of Jiwani, South West Pakistan Coast. Jordan Journal of Biological Sciences 10: 281–287.

Habin, S. & A.R. Yousuf (2012). Benthic macroinvertebrate community of Yousmarg streams (Doodsganga stream and Khanshah Manshah channel) in Kashmir Himalaya. Indian Journal of Ecology and the Natural Environment 4(11): 280–289.

Habin, S. & A.R. Yousuf (2014). Benthic macroinvertebrate community of a fourth order stream in Kashmir Himalaya, India. African Journal of Environmental Sciences and Technology 8(4): 234–238.

Hayslip & Gretchen (2007). Methods for the collection and analysis of benthic macroinvertebrate assemblages in wadeable streams of the Pacific Northwest. Pacific Northwest Aquatic Monitoring Partnership, Cook, Washington.

Hira, S.J., G.M. Mulik & B.H. Khajuria (1955). Some interesting features of the aquatic fauna of the Kashmir Valley. Journal of the Bombay Natural History Society 53(1): 140–143.

Hynes, H.B.N. (1970). The Ecology of Running Waters. Liverpool University Press, England 555 pp.

Linke, S., R.C. Bailey & T.J. Schwid (1999). Temporal variability of stream bioassessments using benthic macroinvertebrates. Freshwater Biology 42: 575–584.

Lydeard, C., R.H. Cowie, W. Ponder, A.E. Bogan, P. Bouchet, S.A. Clark, K.S. Cummings, T.J. Frent, O. Gar- Gominy, D.G. Herbert, R. Hershler, K.E. Perez, B. Roth, M. Seddon, E.E. Strong & F.G. Thompson (2004). The global decline of nonmarine mollusks. BioScience 54: 321–330.

Malhotra, Y.R., K.K. Sharma & M.R. Thakial (1996). Ecology of macro invertebrates from a fish pond. Proceedings of the National Academy of Sciences India 66: 55–59.

Margalef, R. (1958). Temporal succession and spatial heterogeneity in phytoplankton, pp. 323–347. In: Buzzatti-Traverso (ed.). Perspectives in Marine Biology. University of California Press, Berkeley.

Martin, A. (1991). Molluscs as agricultural pests. Outlooks on World Agriculture 20: 167–174.

Mir, K.A. & M. Maleem (2016). District survey report of Pulwama district. Department of Geology and Mining, J&K Srinagar, 26 pp.

Mostafa, O.M.S. (2009). Effect of salinity and drought on the survival of Biomphalaria arabica, the intermediate host of Schistosoma mansoni in Saudi Arabia. Egyptian Academic Journal of Biological Science 11(1): 1–6.

Moulton, S.R., J.L. Carter, S.A. Grotheer, T.F. Cuffney & T.M. Short (2000). Methods of analysis by the US Geological Survey National Water Quality Laboratory; processing, taxonomy, and quality control of benthic macroinvertebrate samples. US Geological Survey Open-File Report, 212 pp.

Nelson, J.W., J.A. Kadlec & H.R. Murkin (1990). Responses by benthic macroinvertebrates to cattail litter quality and timing of litter submergence in a northern prairie marsh. Wetlands 10(1): 47–60.

Pandit, A.K., S.A. Rather, S.A. Bhat & A.Q Shah (2002). Physico-chemical features of freshwaters of Kashmir Himalaya, pp. 112–138. In: Unni, K.S. (ed.). Conservation and Management of Aquatic Ecosystems. Daya Publishing House, Delhi.

Peck, D.V., J.M. Lazorchak & D.J. Klemm (2002). Environmental Monitoring and Assessment Program--Surface Waters: Western Pilot Study Field Operations Manual for Wadable Streams. National Health and Environmental Effects Research Laboratory [and] National Exposure Research Laboratory, Office of Research and Development, US Environmental Protection Agency.

Peeters, E.T. & J.J.P. Gardeniers (1998). Logistic regression as a tool for defining habitat requirements of two common gammarids. Freshwater Biology 39: 605–615.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131–144.

Poff, N.L. & J.V. Ward (1989). Implications of streamflow variability and predictability for lotic community structure: A regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46: 1805–1817.

Primack, R.B. (2002). Essentials of Conservation Biology, 3rd Ed. Sinauer Associates, Sunderland, Massachusetts, 698 pp.

Qadir, M.Y., S.A. Naqash, G.M. Shah, & A.R. Yousuf (1981). Limnology of two trout streams of Kashmir. Journal of Indian Institute of Sciences 63: 137–141.

Ramakrishna & A. Dey (2007). Handbook on Indian freshwater molluscs. AICOPTAX–Mollusca, Zoological Survey of India, 399 pp.

Rao, N.V.S. (1989). Handbook of Freshwater Molluscs of India, Zoological Survey of India, Calcutta, 290 pp.

Rao, N.V.S. (1993). Fresh water molluscs of India. In: Roa K.S. (ed.). Recent Advances in Fresh Water Biology. Anmol Publications Pvt. Ltd., New Delhi, India, 380 pp.

Reddy, V.M. (1995). Soil organisms and litter decomposition in the tropics. Oxford and IBH CO. Pvt. Ltd., 272 pp.

Rosenberg, D.M. & V.H. Resh (1993). Introduction to fresh water biomonitoring and benthic macroinvertebrates, pp. 1–9. In: Rosenberg, D.M. & V.H. Resh (eds.). Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York.

Rosillon, D. (1987). Seasonal variation in the benthos of a chalk trout stream, the River Samson, Belgium. Hydrobiologia 126: 253–262.

Shannon, C. E. & W. Wiener (1949). The Mathematical Theory of Communication. Urbana, University of Illinois Press, 177 pp.

Sharma, K.K., S. Chowdhary & A. Sharma (2010). Malacofauna diversity of river Chenab fed stream (Gho-Manhasan). The Bioscan 6(2): 267–269.

Sharma, R.C. (1986). Effect of physico-chemical factors on benthic
fauna of Bhagirathi river, Garhwal Himalayas. *Indian Journal of Ecology* 13: 133–137.

Silva, E.L., A.J. Rocha, M.F. Leal, O. Dos Santos, J.H. Sousa, A.R.V. Silva, K.K.S. Dantas, E.M.M. Rulim, E.S. Castro, A.C.L. Pacheco & T.G. Pinheiro (2020). Freshwater mollusks from three reservoirs of Piauí, northeastern Brazil. *Biota Neotropica* 20(1): 1–8.

Simpson, E.H. (1949). Measurement of diversity. *Nature* 163: 688pp.

Strzelec, M. & A. Krolczyk (2004). Factors affecting snail (Gastropoda) community structure in the upper course of the Warta river (Poland). *Biologia Bratislava* 59(2): 159–163.

Wagh, G.A., H.A. Qurashi & S. Patil (2019). A Brief Note on Molluscan Diversity From Water Bodies of Amravati MS India. *Bioscience Biotechnology Research Communications* 12(3): 814–819.

Wosu, L.O. (2003). *Commercial Snail Farming in West-Africa - A Guide*. AP Express Publishers Ltd., Nsukka.

Yousuf, A.R., F.A. Bhat & M.D. Mahdi (2006). Limnological features of River Jhelum and its important tributaries in Kashmir Himalaya with a note on fish fauna. *Journal of Himalayan Ecology and Sustainable Development* 1: 37–50.
The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under Creative Commons Attribution 4.0 International License unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

March 2022 | Vol. 14 | No. 3 | Pages: 20703–20810
Date of Publication: 26 March 2022 (Online & Print)
DOI: 10.11609/jott.2022.14.3.20703-20810

**Article**

**Distribution and habitat-use of Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) in Parsa National Park, Nepal**
– Santa Bahadur Thing, Jhamak Bahadur Karki, Babu Ram Lamichhane, Shashi Shrestha, Uba Raj Regmi & Rishi Ranabhat, Pp. 20703–20712

**Communications**

**Habitat preference and population density of threatened Visayan hornbills Penelope p. panini and Rhabdotorrhinus waldeni in the Philippines**
– Andrew Ross T. Reintar, Lisa J. Paguntalan, Philip Godfrey C. Jakosalem, Al Christian D. Quidet, Dennis A. Warguez & Emelyn Peñaranda, Pp. 20713–20720

**Nest colonies of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) on overhead power transmission cables in the agricultural landscape of Cuddalore and Villupuram districts (Tamil Nadu) and Puducherry, India**
– M. Pandian, Pp. 20721–20732

**Status and distribution of Mugger Crocodile *Crocodylus palustris* in the southern stretch of river Cauvery in Melagiris, India**
– Rahul Gour, Nikhil Whitaker & Ajay Kartik, Pp. 20733–20739

**Dragonflies and damselflies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India**
– Ashish Tiple, Vivek Sharma & Sonali V. Padwad, Pp. 20740–20746

**Spatial and temporal variation in the diversity of malaco fauna from Aripal stream of Kashmir Himalaya, India**
– Zahoor Ahmad Mir & Yahya Bakhtiyar, Pp. 20747–20757

**A checklist of blue-green algae (Cyanobacteria) from Punjab, India**
– Yadvinder Singh, Gurdarshan Singh, D.P. Singh & J.I.S. Khattar, Pp. 20758–20772

**Short Communications**

**Breeding biology of Sri Lanka White-eye Zosterops ceylonensis (Aves: Passeriformes: Zosteropidae) in tropical montane cloud forests, Sri Lanka**
– W.D.S.C. Dharmarathne, P.H.S.P. Chandrasiri & W.A.D. Mahaulpatha, Pp. 20773–20779

**Two new species of army ants of the *Aenictus ceylonicus* group (Hymenoptera: Formicidae) from Kerala, India**
– Anupa K. Antony & G. Prasad, Pp. 20780–20785

**Addition of three new angiospermic taxa to the flora of Bangladesh**
– M. Ashrafulzaman, M. Khairul Alam & A.K.M. Golam Sarwar, Pp. 20786–20791

**A new distribution record of *Memecylon clarkeanum* Cogn. (Melastomataceae) to Karnataka from Sharavathi river basin, central Western Ghats, India**
– Malve Sathisha Savinaya, Jogattappa Narayana, Venkataramaiah Krishna & Kalamanji Govindaiah Girish, Pp. 20792–20797

**Notes**

**First record of Doherty's Dull Oakblue *Arhopala khanti* Doherty, 1891 from upper Assam, India**
– Arun Pratap Singh, Pp. 20798–20800

**A new species of *Pancratium* Dill. ex L. (Amaryllidaceae) from Eastern Ghats of India**
– R. Prameela, J. Prakasa Rao, S.B. Padal & M. Sankara Rao, Pp. 20801–20804

**Tribulus ochroleucus (Maire) Ozenda & Quezel (Zygophyllaceae) - a new addition to the flora of India**
– K. Ravikumar, Umeshkumar Tiwari, Balachandran Natesan & N. Arun Kumar, Pp. 20805–20807

**Abnormalities in the female spikelets of *Coxa lacryma-jobi* L. (Poaceae) India**
– Nilesh Appaso Madhav & Kumar Vinoth Chhotupuri Gosavi, Pp. 20808–20810