

Habitat Ecology and Shellfish Diversity of River Burhi Gandak, North Bihar, India

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ABSTRACT

The present study was conducted to investigate the distribution and abundance of shellfish fauna from the river Burhi Gadak in North Bihar, India. The hydro-morphology of the river were studied and revealed that river width varied from 87.34 ± 10.17 to 102.77 ± 11.58 m and maximum river width was recorded in August 2020. The maximum depth was observed between 8.62 ± 0.99 to 13.55 ± 1.21 m and maximum depth was observed in August 2020 and minimum depth ranged from 6.44 ± 0.80 to 9.92 ± 1.06 m and minimum depth was found in June 2021. The maximum water flows varied between 0.55 ± 0.11 to 0.74 ± 0.11 m/s and the minimum flow rate was recorded in August 2020 and minimum water flow ranged from 0.40 ± 0.07 to 0.47 ± 0.06 m/s and low water flow was recorded in June 2021. The investigation recorded a total of 12 shellfish species under 4 orders, 9 families and 10 genera. Identified shellfishes comprised of 5 species of crustaceans (3 species of freshwater prawns and 2 species of crab under 2 orders, 2 families and 3 genera) and 7 species of molluscs (5 species of snails and 2 species of mussels under 2 orders, 7 families and 6 genera). The highest species abundance was observed at Muzaffarpur sampling site having Palaemonidaeas the predominant family with 3 species. The Shanon-Wiener diversity index, Pielou's evenness index and Margalef's species richness index ranged from 2.30 to 2.50, 0.90 to 1.0, 2.0 to 2.30, respectively.

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Authors' Contribution

SC sample collection, species identification and preparing the first version of manuscript. HSM formal analysis and reviewing of the draft of manuscript for final approval. RKR critical reviewing of the research work, literature collection and reviewing drafts of the manuscript for final approval. SK visualization, formal analysis and investigation. OS laboratory observation and data curation. CS technical contribution on data analysis, reviewing the first version of manuscript.

Key words

River width, Depth, Water flow, Species composition of crustaceans and Molluscs

INTRODUCTION

India is endowed with abundant water resources in the form of river 29000 km, reservoirs 3.15 million ha, lakes 0.72 million ha, backwater and lagoons 0.9 million ha, estuaries 0.3 million ha, floodplain wetlands 0.2 m ha, which provides a wide range of opportunities for the growth and development of fisheries sector (ICAR-CIFRI, 2019). The Ganga River system is one of the largest riverine systems in India and its combined length is 8047 km. Gomti, Ghagra, Gandak, and Burhi Gandak rivers are the major tributaries of this river system (Ayyappan *et al.*, 2011). India has rich resources of shellfishes include 2,934

crustacean species (2,430 species of saltwater and 504 species of freshwater crustacean), 5,070 molluscan species (3,370 species of saltwater and 1,700 species of freshwater) (Jena and Gopalakrishnan, 2012). Shellfish are the crucial members of the phylum Arthropoda and Mollusca, which have the biosphere's highest animal biodiversity. The biodiversity index examines the abundance and distribution of distinct species and species richness to further detail society makeup. These indexes help determine the uniqueness and genetic richness of species in a given society (Grace, 2013).

Bihar has significant freshwater resources for the development of fisheries. The Burhi Gandak river originated in Chautarwa Chaur near in West Champaran district of North Bihar. The Burhi Gandak river basin is bordered on the north by the Himalayas, on the south through Ganga River, on the east through Kosi River, and on the west through the great Gandak river, which forms the Gandak's eastern boundary. The Burhi Gandak river has the area of catchment 12,500 sq km, with 10,150 sq km in Bihar and the rest in Nepal. The river abundantly flows through India and it is an important perennial river of North Bihar (Singh *et al.*, 2018).

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MATERIALS AND METHODS

Study area

The present biodiversity investigation was conducted in Burhi Gandak River, North Bihar to study the variation in distribution and abundance of shellfish fauna for a year from July 2020 to June 2021. Motihari (site 1), Muzaffarpur (site 2), and Khagaria were the study locations (site-3). Three sites totaling about 100 km each make up the entire study area (about 300 km). Three of these study stations are positioned upstream (site-1), in the middle stream (site-2) and in the lower stream, respectively (site-3). A global positioning system (GPS) was used to map out the locations of the sampling sites.

Sampling methods, data collection and taxonomic identification

The shellfish samples were collected in the morning between 5.30 am to 10:00 am every month from July 2020 to June 2021, with the help of local fishermen by using traditional boats and locally man-made nets like bamboo-made traps (Ghana) and Peln Jaal to catch the freshwater prawn and crabs and other species like snails, mussels are picked by hands. The collected specimens were identified by using standard taxonomic keys (Ramakrishna and Dey, 2007; Jayachandran, 2001).

Habitat ecology parameters of Burhi Gandak River

Habitat ecological parameters such as river depth, width, flow rate, river substrates, aquatic vegetation and river riparian cover were recorded in the field by using cloth tape, bamboo poles, rope, thermocole and by visual inspection (Table I). The river substrate, aquatic vegetation and riparian cover play an important role in abundance and distribution of shellfishes. These ecological parameters were observed through visual inspection and mean range calculated by using SPSS version: 22.0 Software.

Shellfish faunal diversity indices analysis

The data was collected on monthly basis from all

sampling stations and then recorded the total number of specimens from each sampling station (Table II). The all biodiversity indices of shellfish were calculated by Shanon-Weiner diversity index (H'), Margalef's richness index (d), Pielou's evenness indices (J'), Simpson index ($1-\lambda$), Taxonomic diversity (Δ), Taxonomic distinctness (Δ^*), Average taxonomic distinctness (Δ^+), Variation in taxonomic distinctness (Δ^+) and total phylogenetic diversity ($s\Phi^+$) were used to calculate by computer software package PRIMER V6.1.9 developed by the Plymouth Marine Laboratory, United Kingdom (Clarke and Warwick, 2001).

RESULTS

During the study time a total 12 species of shellfish belonging to 4 orders, 9 families and 10 genera were recorded from Motihari, Muzaffarpur and Khagaria. Identified shellfishes comprised of 5 species of crustaceans (3 species of freshwater prawns and 2 species of crab under 2 orders, 2 families and 3 genera) and 7 species of molluscs (5 species of snails and 2 species of mussels under 2 orders, 7 families and 6 genera). Higher species abundance was observed at Muzaffarpur and the maximum numbers of species were observed in the monsoon season. The average river width of Motihari sampling site was 102.77 ± 11.58 m, Muzaffarpur sampling site was 87.14 ± 12.24 m and Khagaria sampling site was 87.34 ± 10.17 m. The average maximum river depth of River Burhi Gandak was 13.55 ± 1.21 m in Khagaria followed by Muzaffarpur (12.06 ± 0.99 m) and Motihari (8.62 ± 0.99 m). The average maximum flow rate of Burhi Gandak River was 0.74 ± 0.11 m/s in Motihari, 0.65 ± 0.10 m/s in Muzaffarpur and 0.55 ± 0.11 m/s in Motihari. The river substrates were mostly muddy, sandy, rocky and clay content found in all three sites. The higher abundance of aquatic vegetation was observed in Muzaffarpur, while the observed riparian cover was dense at Muzaffarpur.

Table I. Comparative account on habitat ecology of three sampling stations. The values are Mean $\pm$ SEM (range).

Habitat parameters	Motihari (n=12)	Muzaffarpur (n=12)	Khagaria (n=12)
River width (m)	102.77 ± 11.58 (67.13-182.88)	87.14 ± 12.24 (56.38-179.83)	87.34 ± 10.17 (65.53-167.64)
River depth min. (m)	6.44 ± 0.80 (3.04-12.19)	8.74 ± 0.81 (3.96-14.93)	9.92 ± 1.06 (5.00-16.58)
River depth max. (m)	8.62 ± 0.99 (4.57-15.24)	12.06 ± 0.99 (5.87-18.28)	13.55 ± 1.21 (7.31-21.33)
River flow min. (m/sec)	0.42 ± 0.09 (0.12-0.92)	0.40 ± 0.07 (0.12-0.89)	0.47 ± 0.06 (0.24-0.98)
River flow max. (m/sec)	0.55 ± 0.11 (0.18-1.31)	0.65 ± 0.10 (0.21-1.37)	0.74 ± 0.11 (0.29-1.58)

Table II. Shellfish diversity indices. The values are Mean±SEM (range).

Diversity indices	Taxa S (total sp.)	Motihari	Muzaffarpur	Khagaria
N		1749	2176	2089
H'	12	2.42±0.017 (2.30-2.50)	2.44±0.015 (2.40-2.50)	2.43±0.012 (2.35-2.47)
J'	12	0.95±0.016 (0.90-1.00)	0.97±0.015 (0.90-1.00)	0.95±0.011 (0.87-0.98)
d	12	2.13±0.018 (2.00-2.20)	2.22±0.021 (2.10-2.30)	2.15±0.021 (2.04-2.25)

J', Pielous's species evenness; H', Shannon Wiener diversity index; d, Species richness; S, No. of taxa.

DISCUSSION

Habitat ecological parameters

The habitat characteristics like river width, depth flow rate, substrate, aquatic vegetation and the riparian cover were investigated during the study period. The recorded river width was high (67.13 to 182.88 m) in Motihari followed by Muzaffarpur (56.38 to 179.83 m) and Khagaria (65.53 to 167.64 m) which is higher than the earlier report as Johnson and Arunachalam (2009) observed 9.1 to 80 m in river width Western Ghat streams while Johnson *et al.* (2012) observed 54.6 m in Ken River, Madhya Pradesh. The maximum river width was observed during July 2020 and low in June 2021 in the river Burhi Gandak. The increase in water depth started from the monsoon season and was high during July to August. The highest depth of water (7.31 to 21.33 m) was recorded in Khagaria and minimum (3.04 to 12.19 m) in Motihari which was higher than the earlier reports as Johnson and Arunachalam (2009) observed 98.6 cm mean depth in Kallar stream of Western Ghat, India and Johnson *et al.* (2012) record 224 cm mean depth in Ken River, Madhya Pradesh. The maximum water flow rate (0.29 to 1.58 m/s) observed in Khagaria is higher than the previous report Johnson *et al.* (2012) as recorded 0.68 m/s in Ken River in Madhya Pradesh. Agarwal and Singh (2012) recorded 0.50 to 1.46 m/s mean flow rate in Bhagirathi river, Uttarkashi, Agarwal *et al.* (2019) observed 1.52±0.54 m/s mean flow rate in Pinder river, India. As a similar report was observed by Sarkar *et al.* (2010) for *Danio*, *Ompok*, *Bagarius* are attracted to fast-moving water with high flow and depth. There was a positive association between habitat parameters and shellfish abundance in all sites. The high flow rates were reported in the monsoon season and lower in the winter season. The river substrate is highly muddy, sandy clay and rocky while Pati *et al.* (2012)

observed the *Sartoriana spinigera* freshwater crab likes to live in sandy clay in the pond and canal of Odisha. The Maximum number of aquatic vegetation (6) was observed in Muzaffarpur as compared to Khagaria (5) and Motihari (4). River riparian cover was recorded maximum at the middle stream and low in the lower stream of river Burhi Gandak. Such as earlier reports Annawaty *et al.* (2016) observed the freshwater prawn *Caridina* species found in slow-flowing to virtually stagnant water, sandy muddy bottom with aquatic plants roots and dead leaves is the most preferred habitat, while Johnson *et al.* (2012) observed some species like *Danio rerio* and *Rasbora daniconius* chiefly affected by the altitude of river, riparian cover. A similar report Bhat (2004) observed small stones and rocks were associated with species like *Mystus malabaricus*, *Oreochromis nashii*, while more sand and silt substrate was associated with species like *Glossogobius giuris*, and *Puntius ticto* and *Mastacembelus armatus* species were found in high riparian vegetation in Western Ghat, India.

Species diversity, richness, distribution and abundance

The present research was conducted from July 2020 to June 2021 for 12 months duration in the Burhi Gandak river to study variation in distribution and abundance of shellfish from the Burhi Gandak River. A total 12 species of shellfish have been recorded belonging to 4 orders, 9 families and 10 genera which is lower than the earlier records of Prabhakar and Roy (2008) who recorded 20 species of molluscs and 10 species of crustacean from the Kosi river of North Bihar; Rao (2001) recorded 15 species of molluscan, and 04 species of crustacean in the upper stretch of river Ganga; Ramesha *et al.* (2013) observed 19 species of freshwater bivalve belonging to 3 families and 5 genera in Cauvery river, India, Waghmare and Kulkarni (2015) observed 15 molluscs species which includes 9 species of Bivalvia and 6 species of Gastropoda in Lendi River, Maharashtra, Wagh *et al.* (2019) reported 30 species of molluscan fauna comes under 2 categories, 6 orders, 12 family and 17 genera from river Ghaggar in Maharashtra. Raghunathan and Valarmathi (2007) recorded 10 species of freshwater prawns and crabs from a paddy field in Singaperumalkoil, Chennai, which is less than the shellfishes recorded during present study. The average taxonomic distinctness index (Delta+) estimated 12 months was 90.61.

The Shannon-Wiener species diversity data was calculated according to month and sampling sites during the study period. Among the studies of Burhi Gandak river the higher H' value for the overall studied period ranged from 2.40 to 2.50 in Muzaffarpur followed by 2.30 to 2.50 in Motihari and 2.35 to 2.47 in Khagaria which is higher than the earlier records such as Soomro

et al. (2016) observed H' value ranged from 0.51-1.17 in Kikaijima Island, Japan; *Alhassan et al.* (2020) recorded H' value 0.97 in Kubanni reservoir, Nigeria; *Azadi and Alam* (2011) observed Shannon diversity index 0.25-0.32 from the Halda river, Bangladesh; *Hamid and Wardiatno* (2018) recorded H' value 0.812–0.893 in Lasongko Bay in Indonesia; *Sarwade et al.* (2015) reported Shannon index 1.84 from the freshwater region, Maharashtra; *Olawusi-Peters and Ajibare* (2014) observed H' value 0.26-0.92 in Nigeria and *Johnson et al.* (2012) observed Shannon index ranged from 0.59-3.48 in Ken river, Madhya Pradesh. The Pielou's evenness index ranged from 0.90 to 1.00 in Muzaffarpur, 0.90 to 1.00 in Motihari and 0.87 to 0.98 in Khagaria which is higher than some earlier records as in the case of *Azadi and Alam* (2011) observed Evenness value from 0.27 to 0.35 in Halda river in Bangladesh; *Hamid and Wardiatno* (2018) observed Evenness index ranging between 0.592–0.683 in Lasongko Bay in Indonesia and *Sarwade et al.* (2015) recorded evenness value 0.90 from the freshwater region of Maharashtra. In the present investigation, the Margalef's richness ranged from 2.10 and 2.30 in Muzaffarpur, 2.04 to 2.25 in Khagaria and 2.00 to 2.20 in Motihari. Higher species richness was observed in Muzaffarpur followed by Khagaria and Motihari which is higher than the previous observation as *Olawusi-Peters and Ajibare* (2014) observed species richness 0.38-0.91 in Nigeria; while *Soomro et al.* (2016) recorded d value 0.38-0.99 in Kikaijima Island, Japan and *Johnson et al.* (2012) observed Magalef's species richness value ranged 0.59-3.48 from Ken River, Madhya Pradesh. The average taxonomic distinctness index value similar in season and sitewise. The average taxonomic distinctness index is the sum of all the species list pairs' average taxonomic distances apart. The average taxonomic distinctness index (Δ^+) estimated was 90.61 in all monthwise, seasonwise and sitewise in all 12 months (Table III). *Sudhan* (2017) estimated lower value of Δ^+ index ranged from 71.21 to 90.14 in Pechiparai reservoir. The mean phylogenetic diversity index is calculated by dividing the total phylogenetic diversity index by the number of species, and it reflects the taxonomic width or overall taxonomic path length. The total phylogenetic diversity index ($s\Phi^+$) calculated was 860 in all sampling sites, seasonwise and monthwise. *Sudhan* (2017) observed phylogenetic diversity index ranged from 890 and 1966 in Pechiparai reservoir. *Pavinkumar* (2014) recorded higher phylogenetic diversity value in selected three estuaries of Tamil Nadu namely Manakudy estuary, Korampallam-Thermal estuary and Punnakayal estuary.

Cluster analysis is useful for determining the natural grouping of samples, inside a group being more similar to one another than samples from separate groups (*Clarke and Warwick, 2001*). Bray-curtis similarity based on counts

in all three sampling sites. The Bray-curtis similarity analysis of all three sampling stations given in Figure 1. Motihari performed 87% similarity with Muzaffarpur and 92% with Khagaria as same as Muzaffarpur performed 87% similarity with Motihari and 90% with Khagaria and also Khagaria performed 92% commonality with Motihari and 90% with Muzaffarpur. The group in the dendrogram was formed between Motihari and Khagaria with 92% similarity. While comparing similarity between all three sampling sites based on mothwise, seasonwise and sitewise. The monsoon and post-monsoon show 99% similarity and post-monsoon and pre-monsoon shows 97% (Fig. 2).

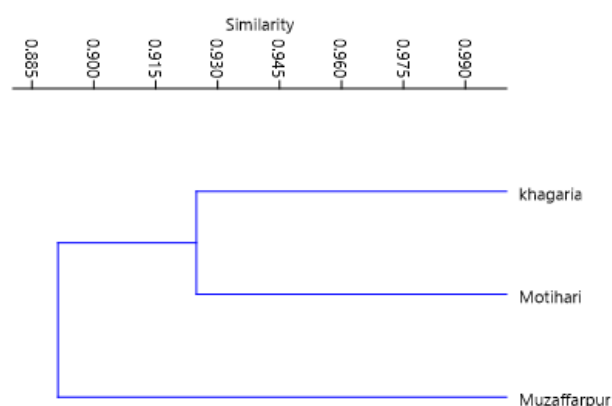


Fig. 1. Bray-Curtis Similarity analysis of selected sampling site (Motihari, Muzaffarpur, Khagaria).

During the study time the higher species abundance was observed at Muzaffarpur (2169 individuals) followed by Khagaria (2089 individuals) and Motihari (1767 individuals) and the maximum numbers of species were observed in the monsoon season. The diversity index was calculated for Motihari, Muzaffarpur and Khagaria sampling stations. The Shannon-Weiner diversity index ranged from 1.30 to 1.50 from all three stations. The Pielou's evenness ranged from 0.90 to 1.00 in Motihari, Muzaffarpur and Khagaria. The Magalef's species richness index (d) varied between 2.0 to 2.30 in all three stations. According to the hierarchical clustering, the highest similarity was observed for Motihari and Khagaria (92%) and the lowest between Muzaffarpur and Motihari (87%). While the season wise post-monsoon shows 99% similarity. According to seasonwise maximum similarity between season was 99.65% similarity between monsoon and post-monsoon season and minimum similarity season was 97.22% between post-monsoon 2020 and pre-monsoon 2021. The average taxonomic distinctness index was 90.61 in all monthwise, seasonwise and sitewise also.

Table III. Monthly wise and season wise diversity indices of shellfishes.

Sample	N	d	J'	H'	1-Lambda	Delta	Delta*	Delta ⁺	sPhi+
Monthwise diversity indices									
Jul-2020	596	2.0	1.0	2.50	0.9174	83.16	90.65	90.61	860
Aug-2020	531	2.1	1.0	2.50	0.9169	83.34	90.91	90.61	860
Sep-2020	495	2.2	1.0	2.50	0.9174	83.23	90.72	90.61	860
Oct-2020	502	2.1	0.9	2.40	0.9150	82.07	89.69	90.61	860
Nov-2020	542	2.1	0.92	2.40	0.9078	80.23	88.38	90.61	860
Dec-2020	560	2.2	0.87	2.40	0.9097	81.90	90.04	90.61	860
Jan-2021	543	2.2	0.98	2.38	0.9084	81.22	89.41	90.61	860
Feb-2021	537	2.1	0.98	2.40	0.9038	80.09	88.62	90.61	860
Mar-2021	460	2.1	1.0	2.47	0.9150	82.08	89.70	90.61	860
Apr-2021	421	2.2	0.9	2.40	0.9141	81.65	89.32	90.61	860
May-2021	415	2.3	0.9	2.50	0.9135	81.15	88.83	90.61	860
Jun-2021	412	2.1	0.9	2.30	0.9092	80.03	88.03	90.61	860
Seasonwise diversity indices									
Monsoon	159	2.169	0.9995	1.07	0.9222	83.52	90.56	90.61	860
Postmonsoon	160	2.168	0.9842	1.06	0.9203	82.81	89.98	90.61	860
Premonsoon	142	2.219	0.9240	1.07	0.9220	82.93	89.94	90.61	860

N, Total No. of individuals; d, Margalef's species richness; J', Pielous's species evenness; H', Shannon Wiener diversity index; 1-Lambda, Simpson; Delta, Taxonomic diversity; Delta*, Taxonomic distinctness; Delta⁺, Average taxonomic distinctness index; sPhi+, Total phylogenetic diversity.

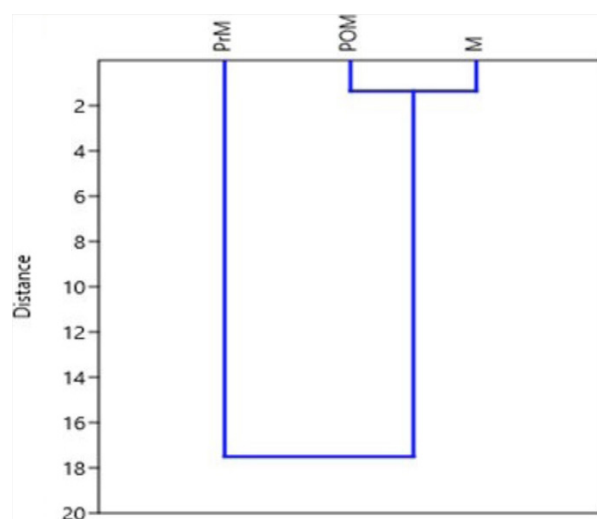


Fig. 2. Dendrograms showing similarities between season wise bases on shellfish species composition in all three sampling sites.

The total phylogenetic diversity index calculated was 860 in all three sites. Shellfish diversity, richness and evenness showed a similar trend at all the sampling sites.

Higher river width was observed at Motihari followed by Khagaria and Muzaffarpur and maximum river depth and flow was recorded at Muzaffarpur. This could be the reason for higher species abundance at Muzaffarpur compared to other 2 sampling sites

The current study provides a valid information pertinent to the shellfish assemblages in the Burhi Gandak river and this information is used to evaluate future species populations. Industrial waste, domestic waste and agricultural runoff were some of the major threats to habitat and diversity of shellfish fauna in the river Burhi Gandak. The study also suggests that the evaluation of the river primary economic benefits might show the precise effectiveness and trigger after actions for developing laws, rules and regulations into place. The habitat of Burhi Gandak needs to be conserved because this river basin harbours a diverse group of freshwater finfishes and shellfishes.

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IRB approval ethical statement

IRB Approval have been given by the advisory committee members and all the procedures were carried out according to the institutional guidelines.

Statement of conflict of interest

The authors have declared no conflict of interest.

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