Himalayan J. Soc. Sci. & Humanities ISSN: 0975-9891 https://doi.org/10.51220/hjssh.v20i1.3
Vol. 20, (2025) 15-25

Spatial and Temporal Patterns of Occupational Structure in Haldwani Block: A Village-Level Analysis (1991–2011)

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Received: 29.09.2025; Revised: 30.12.2025; Accepted: 31.12.2025

Abstract: Occupational structure is a key indicator of the economic and social development of any country or region. The segment of the population engaged in economically productive activities constitutes the working population. According to the Census of India (2011), a worker is defined as a person who has participated in any economically productive work, encompassing full-time, part-time, and seasonal employment. Workers are further classified into main and marginal categories. Based on industrial classification, both main and marginal workers are grouped into four sectors: cultivators, agricultural labourers, household industry workers, and other workers. The occupational structure reflects the level of development of a region, as economic progress is generally associated with a decline in primary sector employment and a corresponding increase in secondary and tertiary sectors. The present study aims to examine the work participation rate of villages in the Haldwani Block and to analyse the spatial pattern of occupational structure at the village level. The study is based on secondary data from the District Census Handbooks of Nainital district for 1991, 2001, and 2011. The findings indicate a predominance of primary occupations, though gradual growth in secondary and tertiary sectors is evident over time.

Keywords: Occupational Structure; Cultivators; Agricultural labour; Household industry worker; Other worker; Work Participation Rate

Introduction

The district of Uttarkashi holds immense hydrological significance as it is the source region of two major rivers of northern India, the Ganges and the Yamuna. The Ganges, known as the Bhagirathi in its upper reaches, originates from the Gaumukh glacier. In recent decades, the expansion of small hydropower projects has accelerated globally, particularly in mountainous and rural regions. These projects are often promoted as environmentally sustainable and economically viable alternatives to large hydropower schemes. In Uttarkashi, the Bhagirathi River has emerged as a major hub for hydropower development, with several projects that are operational, under construction, planned, or cancelled.

Among the most prominent initiatives are the Maneri Bhali Hydropower Projects operated by the Uttarakhand Jal Vidyut Nigam Ltd. (UJVNL). The Maneri Bhali Stage I Power Project, located approximately 8.5 km from Uttarkashi at Maneri, has an installed capacity of about 90 MW. The Maneri Bhali Stage II Power Project, situated within Uttarkashi town, has a significantly higher capacity of 304 MW (Dharasu HEP, 4×76 MW). While these projects contribute substantially to regional energy demands, they also impose notable environmental costs on the riverine ecosystem.

The Bhagirathi River, a vital component of the Garhwal Himalayan river system, supports rich aquatic biodiversity. However, anthropogenic interventions, particularly dam construction and water diversion, have profound ecological consequences. Reduced water flow in the main channel alters natural temperature regimes and physico-chemical characteristics of water, often leading to habitat degradation for microorganisms and aquatic flora. Reservoirs behind dams also influence water quality by trapping sediments and pollutants, which may later be released in a regulated manner. Such disruptions interfere with the natural flow regime essential for fish migration and the maintenance of aquatic ecosystem health (Tiwari & Tiwari 2022). Large dams, although important for power generation, irrigation, and flood control, significantly affect river ecosystems both upstream and downstream (Hussain et al. 2012; Siciliano et al. 2018).

The Bhagirathi River remains the principal source of freshwater for Uttarkashi, meeting the daily needs of local communities. Therefore, balancing developmental priorities with ecological sustainability is crucial for safeguarding the river's long-term health. Integrating ecological data into hydropower impact assessments has become increasingly important for environmental planning and energy policy formulation in hydro-dependent regions (Myronidis et al. 2008; Tomczyk & Wiatkowski 2020).

Plankton communities, including phytoplankton and zooplankton, play a central role in freshwater ecosystems. Phytoplankton form the base of aquatic food webs, while zooplankton serve as a critical link between primary producers and higher trophic levels. The productivity and stability of aquatic ecosystems are closely associated with plankton abundance and diversity (Guy 1992). These organisms are widely used as bio-indicators for monitoring water quality and pollution levels (Mathivanan & Jayakumar 1995). Zooplankton, in particular, are highly sensitive to environmental changes and serve as reliable indicators of ecosystem health (Nikolsky 1999; Sládeček 1983).

Hydropower projects, including run-of-river and reservoir-based systems, can disrupt natural flow variations essential for sustaining plankton communities. Altered thermal regimes, reduced flow, and habitat loss directly influence plankton composition and distribution. While most studies have focused on large reservoirs (Fantin-Cruz et al. 2015; Wang et al. 2016; Zhao et al. 2020), recent research highlights ecological impacts of smaller diversion-based hydropower plants as well (Kuriqi et al. 2021). Cumulative impact assessments emphasize the importance of evaluating the combined effects of multiple projects on river ecosystems (Tonk & Kumar 2016).

Previous studies indicate that zooplankton diversity in the Bhagirathi River exhibits strong seasonal variation, with higher diversity in winter and complete absence during the monsoon (Tiwari & Tiwari 2020). The present study aims to evaluate the impacts of hydropower development on local communities, assess water quality parameters, and analyze changes in phytoplankton and zooplankton communities associated with dam construction.

Study Area

A reservoir wall was constructed on the Bhagirathi River at the village of Maneri, creating an artificial (man-made) water reservoir approximately 1230 meters in length. At this location of Maneri Bhali Phase I , two study sites were selected: Site 01 and Site 02. A second location was selected at Maneri Bhali II, this study sites were also identified: Site 01 and Site 02, as shown in Fig. No. 1.

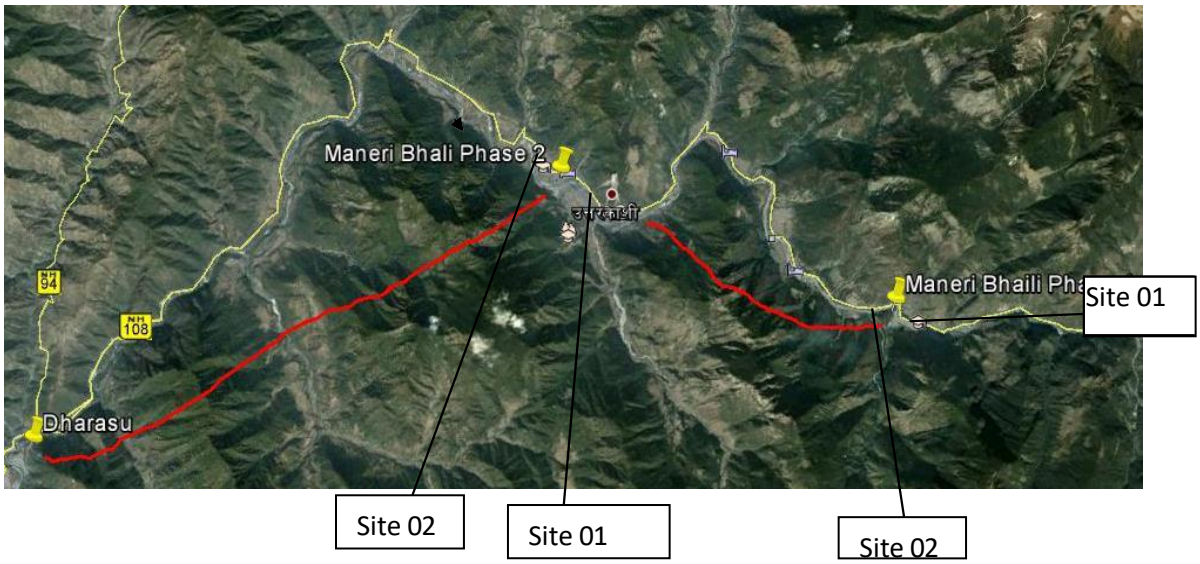

Fig 1: Location of sampling site at Maneri Bhali Phase 1 & phase II.

Material and Methods

Water samples were collected from four designated sampling sites: Site I (S1) and Site II (S2) from Maneri Dam Phase I, and Site I (S1) and Site II (S2) from Maneri Dam Phase II. The samples were collected in clean plastic jerry cans, properly labeled, and transported to the laboratory with due precautions to avoid contamination. The study was conducted over a one-year period from January 2019 to December 2019. Various physico-chemical parameters of the collected water samples were analyzed

following standard methods outlined by Trivedi and Goel (1986) and APHA (2005). The key water quality parameters assessed included air temperature, water temperature, pH, turbidity (in NTU), dissolved oxygen (DO), and biochemical oxygen demand (BOD).Zooplankton identification was performed microscopically using a Sedgwick-Rafter counting cell. The phytoplankton population was also estimated at all four sampling sites. For taxonomic identification of phytoplankton, standard references used included Needham and Needham (1962) and Ward and Whipple (1992).

Results and Discussion

Dams and reservoirs play a crucial role in meeting the essential needs of the local population in Uttarkashi. These include providing water for drinking and irrigation, enabling flood control, supporting fisheries, generating hydroelectric power, facilitating inland navigation, and offering recreational opportunities. However, the construction of dams also has significant ecological

consequences. The natural flow regime of the river is altered, which in turn affects the physical, chemical, and biological characteristics of the aquatic ecosystem. These changes can disrupt the habitat and migration patterns of aquatic organisms, including zooplankton and fish species, ultimately impacting river biodiversity and ecological balance.

Dissolve oxygen(DO) :The Bhagirathi River exhibited marked seasonal variations in Dissolved Oxygen (DO) concentrations, with the highest levels recorded during the colder months and a gradual decline leading to the lowest levels in summer. These elevated DO levels in winter can be attributed to lower turbidity, reduced photosynthetic activity, and decreased water temperatures, which enhance the solubility of oxygen in water. At Site I (Phase I, before the dam wall), the maximum dissolved oxygen (DO) concentration was recorded in January at 13.02 ± 0.166 mg/L, while the minimum was observed in July at 9.4 ± 0.05 mg/L (Table 1). Similarly, at Site II (Phase I, after the dam wall), the highest DO level was also recorded in January at 12.1 ± 0.2 mg/L, and the lowest in July at 8.93 ± 0.08 mg/L.

In Phase II, at Site I (before the dam wall), the maximum DO concentration was recorded in January at 14.07 ± 0.2 mg/L, whereas the minimum value was observed in May at 8.37 ± 0.03 mg/L. At Site II (Phase II, after the dam wall), the highest DO concentration was observed in February at 12.27 ± 0.14 mg/L, while the lowest values were recorded in both April and July at 9.1 ± 0.1 mg/L.

DO concentrations were consistently lower during the summer months (April and July), likely due to the reduced solubility of gases at higher temperatures (Hynes, 1978). Additionally, decreased water volume in summer, results in more concentrated pollutants, which increases oxygen demand for the oxidation of organic matter (Sharma, Lal, & Pathak, 1981). Conversely, higher DO levels during the winter months (e.g., January) can be attributed to the greater solubility of oxygen at lower temperatures (Verma & Rani, 1984).

A notable deviation was observed at Maneri Bhali Phase I, after the dam site, where DO levels did not follow the typical winter increase. Instead, DO remained relatively constant or even declined during peak winter months. This anomaly is attributed to the severe water shortage at the site during winter, as river flow is nearly absent due to water being diverted through tunnels for hydroelectric power generation.

Temperature: At the site before the dam wall in Maneri Bhali Phase I, the maximum air temperature was recorded at 30°C in August 2019, while the minimum was 11°C in January 2019. At the same location, the water temperature (also referred to as depth temperature) reached a maximum of 17°C in August 2019 and dropped to a minimum of 5°C in January 2019 (Table 2).

Table 1: Monthly recorded Dissolve oxygen (mg.l^{-1}) of the Project Phase I- site I& II and Project Phase II- site I & II Bhagirathi river during the year 2019

	Project Phase I				Project Phase II			
	Site 1	Se	Site2	Se	Site 1	Se	Site2	Se
Jan	13.02	0.166	12.1	0.2	14.07	0.06	12.08	0.08
Feb	11.67	0.166	10.7	0.2	11.67	0.08	12.27	0.14
Mar.	9.93	0.12	9.33	0.03	9.1	0.1	8.33	0.06
Apr.	9.5	0.13	9.47	0.06	8.4	0.1	9.1	0.1
May	9.6	0.05	9.6	0.06	8.37	0.03	9.17	0.08
June	9.57	0.03	8.97	0.03	9.1	0.1	9.7	0.15
July	9.4	0.05	8.93	0.08	9.43	0.03	9.1	0.05
Aug	10.07	0.06	9.33	0.06	10.33	0.08	9.33	0.03
Sep	10.33	0.033	9.3	0.057	9.77	0.08	9.03	0.06
Oct	10.57	0.03	9.03	0.033	10.5	0.17	9.53	0.14
Nov	11	0.11	9.4	0.05	9.8	0.08	9.07	0.14
Dec	11.6	0.05	10.1	0.057	10.17	0.08	8.53	0.14

At Maneri Bhali Phase I, after the dam wall, the highest air temperature was observed at 31°C in July 2019, and the lowest was 12°C in January 2019. The water temperature peaked at 18°C in August 2019 and reached a minimum of 6°C in January 2019 (Table 2).

In Maneri Bhali Phase II, at the site before the dam wall, the maximum air temperature was recorded at 32°C in July 2019, with a minimum of 12°C in January 2019. The water temperature reached its highest value of 17°C in both July and August 2019, and the lowest at 5°C in January 2019 (Table 2).

At Maneri Bhali Phase II, after the dam wall, the maximum air temperature was recorded at 32°C in May 2019, and the minimum at 13°C in January 2019. The water temperature was highest at 16°C in July 2019, and lowest at 6°C in January 2019 (Table 2).

Table 2: Monthly recorded Air and Depth Tem.^{0}C of Project Phase I-site I& II and Project Phase II- site I& II Bhagirathi river in the year 2019

	Project Phase I				Project Phase II			
	Site 1		Site 2		Site 1		Site 2	
	Air	Depth	Air	Depth	Air	Depth	Air	Depth
Jan	11	5	12	6	12	5	13	6
Feb	22	8	15	10	16	9	26	8
Mar.	26	13	27	12	28	13	28	12
Apr.	28	16	28	12	31	15	29	14
May	26	14	30	13	32	15	32	15
June	27	15	30	13	31	15	30	14
July	28	16	31	15	32	17	30	16
Aug	30	17	30	18	29	17	28	14
Sep	26	16	28	15	31	16	29	15
Oct	25	15	30	14	26	13	26	13
Nov	23	11	26	11	25	12	25	11
Dec	22	7	21	7	15	9	16	10

In general, higher air and water temperatures were recorded during the monsoon months, particularly between July and August, likely due to increased solar radiation, higher ambient temperatures, and reduced canopy cover, all of which contribute to elevated thermal conditions in the river system.

Lower water temperatures during the winter months were also reported by Welch, P.S. (1952) and are likely due to minimal rainfall and cold weather conditions. In contrast, higher temperatures observed during April and May were associated with longer photoperiods, intense sunshine, wind activity, and other climatic factors that contribute to surface warming.

A slight increase in water temperature at Site II (after the dam wall) was observed. This may be attributed to the reduced water levels, which allow for more rapid warming of the water column due to shallow depth and increased exposure to solar radiation. Similar findings were reported by NTPC Limited (2011) at the same site, where minimized water flow was associated with elevated thermal gradients.

Carbon Dioxide (CO_2) Concentration: In Maneri Bhali Phase I (before the dam wall), at Site I, the maximum CO_2 concentration was recorded in April at 3.10 ± 0.012 mg/L, while the minimum was 1.60 ± 0.003 mg/L in January (Table 3). At Site II (after the dam wall), the CO_2 concentration peaked in July at 3.01 ± 0.003 mg/L, and was lowest in January at 1.69 ± 0.003 mg/L (Table 3).

In **Phase II**, at **Site I** (before the dam), CO_2 concentration was highest in **May** at **3.3 ± 0.005 mg/L** and lowest in **January** at **1.47 ± 0.003 mg/L**. At **Site II** (after the dam wall), the CO_2 level peaked in **July** at **3.08 ± 0.011 mg/L** and dropped to **1.69 ± 0.008 mg/L** in **January** (Table 3).

Across both phases, CO_2 levels were slightly higher **after the dam wall** compared to before. This could be due to **reduced free CO_2** as a result of **photosynthetic uptake**, as also reported by **Sharma R.C. (2005)**. A **negative correlation** was observed between **free CO_2** and **dissolved oxygen (DO)** levels.

pH and Turbidity: The pH of the Bhagirathi River ranged from 7.1 to 7.9 across Maneri Bhali Phases I and II (Table 4), indicating a slightly alkaline environment.

Turbidity levels were highest during the **monsoon months (August)** and lowest in **winter months**, consistent across all sites:

Phase I, Site I (before dam): Max: **160.3 ± 0.67 NTU** (Aug), Min: **0.9 ± 0.03 NTU** (Feb)

Phase I, Site II (after dam): Max: **162.7 ± 0.33 NTU** (Aug), Min: **1.7 ± 0.09 NTU** (Feb)

Phase II, Site I (before dam): Max: **151.0 ± 0.58 NTU** (Aug), Min: **0.9 ± 0.06 NTU** (Jan)

Phase II, Site II (after dam): Max: **152.0 ± 0.58 NTU** (Aug), Min: **1.3 ± 0.03 NTU** (Feb) (Table 5)

The increase in turbidity during monsoon is attributed to **surface runoff**, which introduces **silt, sand, clay**, and **organic/inorganic matter** into the river. Construction activities and **muck deposition** also contributed to higher turbidity levels downstream of the dam. Similar findings were noted by **Badola**

S.P. (2009) and **Schmitz W. (1961)**, who highlighted the impact of turbidity on **light penetration** and overall water quality.

Table 3: Monthly recorded CO2 (mg l^{-1}) of Project Phase I-site I& II and Project Phase II-site I& II Bhagirathi river in the year 2019

	Project Phase I				Project Phase II			
	Site 1	Se	Site 2	Se	Site 1	Se	Site 2	Se
Jan	1.61	0.003	1.69	0.003	1.47	0.003	1.69	0.008
Feb	1.76	0.005	1.83	0.003	1.76	0.005	1.83	0.003
Mar.	2.05	0.003	2.2	0.005	2.27	0.008	2.42	0.005
Apr.	3.10	0.012	2.79	0.014	2.93	0.008	2.64	0.01
May	2.86	0.011	2.71	0.014	3.3	0.005	3.08	0.011
June	2.93	0.008	2.86	0.01	2.79	0.006	2.42	0.005
July	2.71	0.008	3.01	0.003	2.64	0.005	2.79	0.003
Aug	2.35	0.01	2.64	0.01	2.05	0.025	2.71	0.01
Sep	2.2	0.01	2.42	0.01	2.57	0.01	2.86	0.01
Oct	1.91	0.01	2.2	0.01	2.2	0.01	2.57	0.01
Nov	1.83	0.01	2.05	0.01	2.57	0.01	2.79	0.01
Dec	1.76	0.01	1.91	0.008	1.91	0.006	2.42	0.01

Table 4: Monthly recorded pH of Project Phase I-site I& II and Project Phase II- site I& II Bhagirathi river in the year 2019

	Project Phase I				Project Phase II			
	Site 1	Se	Site 2	Se	Site 1	Se	Site 2	Se
Jan	7.7	0.000	7.8	0.000	7.4	0.000	7.6	0.000
Feb	7.5	0.000	7.5	0.000	7.2	0.000	7.4	0.000
Mar.	7.4	0.000	7.5	0.000	7.3	0.000	7.4	0.000
Apr.	7.8	0.000	7.6	0.000	7.5	0.000	7.7	0.000
May	7.5	0.000	7.6	0.000	7.6	0.000	7.8	0.000
June	7.2	0.000	7.3	0.000	7.4	0.000	7.4	0.000
July	7.4	0.000	7.5	0.000	7.1	0.000	7.2	0.000
Aug	7.2	0.000	7.6	0.000	7.1	0.000	7.3	0.000
Sep	7.3	0.000	7.3	0.000	7.3	0.000	7.3	0.000
Oct	7.4	0.000	7.5	0.000	7.4	0.000	7.5	0.000
Nov	7.5	0.000	7.6	0.000	7.7	0.000	7.7	0.000
Dec	7.5	0.000	7.6	0.000	7.4	0.000	7.5	0.000

Table 5: Monthly recorded Turbidity (NTU) of Project Phase I-site I& II and Project Phase II, site I& II Bhagirathi river in the year 2019

	Project Phase I				Project Phase II			
	Site1	Se	Site 2	Se	Site 1	Se	Site 2	Se
Jan	1.0	0.13	2.8	0.09	0.9	0.06	1.4	0.07
Feb	0.9	0.03	1.7	0.09	1.0	0.09	1.3	0.03
Mar.	5.1	0.07	5.3	0.10	3.3	0.12	3.6	0.06
Apr.	6.0	0.17	8.5	0.10	8.1	0.13	5.2	0.15
May	30.7	0.37	32.4	0.19	31.5	0.29	37.2	0.12
June	55.3	0.67	57.2	0.17	56.3	0.33	57.5	0.29
July	144.8	0.42	152.2	0.10	115.5	0.29	120.5	0.29
Aug	160.3	0.67	162.7	0.33	151.0	0.58	152.0	0.58
Sep	17.6	0.30	51.4	0.31	32.0	0.58	45.7	0.33
Oct	11.7	0.33	5.5	0.29	18.9	0.21	19.2	0.09
Nov	2.8	0.10	2.3	0.15	1.0	0.09	1.3	0.13
Dec	1.0	0.03	2.4	0.13	1.2	0.12	2.1	0.03

Biochemical Oxygen Demand (BOD):

BOD levels were highest during **August** (monsoon) and lowest during **January** (winter) at all sites:

Phase I, Site I (before dam): Max: **4.33 ± 0.15 mg/L**, Min: **0.70 ± 0.03 mg/L**

Phase I, Site II (after dam): Max: **4.62 ± 0.01 mg/L**, Min: **0.86 ± 0.01 mg/L**

Phase II, Site I (before dam): Max: **4.71 ± 0.01 mg/L**, Min: **0.62 ± 0.02 mg/L**

Phase II, Site II (after dam): Max: **4.83 ± 0.07 mg/L**, Min: **1.23 ± 0.03 mg/L** (Table 6)

These results align with findings by **Sati A. et al. (2011)**, who reported elevated BOD during monsoon due to increased organic load. The **NTPC (2011)** report also observed higher BOD levels downstream of the Maneri Bhali dam in Phase I. However, in Phase II, variations in BOD were less pronounced.

Plankton Diversity and Ecological Impacts:

The study documented a **reduction in phytoplankton and zooplankton diversity** downstream of the dam. This change is likely due to **altered flow regimes**, **reduced water levels**, and **temperature fluctuations**, especially during winter when the **riverbed runs almost dry**.

Phytoplankton Diversity:

Phase I, Site I **(before dam):** 41 genera (Bacillariophyceae: 23, Chlorophyceae: 10, Myxophyceae: 7, Xanthophyceae: 1)

Phase I, Site II **(after dam):** 31 genera (Bacillariophyceae: 17, Chlorophyceae: 9, Myxophyceae: 5, Xanthophyceae: Nil)

Phase II, Site I **(before dam):** 45 genera (Bacillariophyceae: 25, Chlorophyceae: 10, Myxophyceae: 9, Xanthophyceae: 1)

Phase II, Site II **(after dam):** 34 genera (Bacillariophyceae: 19, Chlorophyceae: 9, Myxophyceae: 6, Xanthophyceae: Nil)

Bacillariophyceae remained the **dominant group** across all sites. This trend is consistent with observations by **Joshi et al. (1996)**, who reported seasonal variations in plankton density, with higher values in winter and reductions during the monsoon due to turbidity.

Zooplankton Composition and Density:

Zooplanktons were primarily composed of: Cladocera 3 genera, Protozoa 2 genera, Copepoda 4 genera, Rotifera 2 genera.

Zooplankton density:

Phase I: Declined from **16 units/L** (before dam) to **14 units/L** (after dam)

Phase II: Declined from **18 units/L** to **15 units/L**

Zooplankton are vital indicators of water quality and form an essential component of the **aquatic food web** (Sladecek, V., 1983). The decline in both **phytoplankton and zooplankton** downstream highlights the ecological impact of hydropower operations. According to **Tomczyk & Wiatkowski (2021)**, such studies are critical for understanding how **dam construction** and **flow regulation** affect riverine ecosystems.

Table 6: Monthly recorded BOD (mg l^{-1}) of Project Phase I-site I& II and Project Phase II, site I& II Bhagirathi river in the year 2019

	Project Phase I				Project Phase II			
	Site 1	Se	Site 2	Se	Site 1	Se	Site 2	Se
Jan	0.7	0.03	0.86	0.01	0.62	0.02	1.23	0.03
Feb	1.47	0.01	0.95	0.01	0.97	0.01	1.97	0.01
Mar.	2.1	0.12	2.43	0.03	2.11	0.01	2.87	0.01
Apr.	2.28	0.1	2.63	0.01	2.84	0.02	3.12	0.01
May	2.13	0.01	2.53	0.01	3.53	0.03	3.74	0.02
June	3.17	0.02	3.1	0.06	3.63	0.09	3.23	0.03
July	3.21	0.03	3.2	0.05	3.8	0.06	3.97	0.01
Aug	4.33	0.15	4.62	0.01	4.71	0.01	4.77	0.01
Sep	3.92	0.04	4.3	0.12	4.57	0.07	4.83	0.07
Oct	2	0.12	2.77	0.09	3.6	0.12	3.23	0.09
Nov	1.6	0.13	1.9	0.06	3.27	0.03	3.8	0.06
Dec	0.8	0.06	1.5	0.06	1.72	0.01	2.03	0.04

Conclusion

The management of river water has long been a critical concern, particularly in regions where rivers constitute the primary natural resource for human sustenance and ecological stability. Sustainable river water management requires basin-specific planning that is technically sound, economically

viable, and supported by comprehensive field surveys and scientific analyses. Since early civilization, humans have relied on dams and reservoirs to store excess river water during periods of high flow for use during dry seasons. Rivers, as major freshwater sources, continue to play an essential role in meeting the daily needs of local communities, including those in Uttarkashi.

The present study offers important insights into the water quality of the Bhagirathi River in the vicinity of the Maneri Dam. One notable observation is that river stretches experiencing extreme fluctuations in water levels, including near-dry conditions, show signs of ecological recovery when water levels are restored. It is hypothesized that natural cycles of alternating high and low flows contribute to the replenishment of aquatic biodiversity. Such cycles support the normalization of physico-chemical parameters, facilitate sediment exchange, and enable a more even redistribution of aquatic organisms. However, these recovery processes are constrained by time and may be severely disrupted under prolonged extreme flow conditions.

Water level fluctuations induced by the Maneri Dam exert both direct and indirect impacts on the aquatic environment. These include alterations in river morphology and bottom substrates, deterioration of water quality, and a marked reduction in the diversity and density of aquatic biota in the Bhagirathi River. Impaired ecosystem functioning further exacerbates these effects. Studies indicate that dam-regulated rivers generally exhibit lower species richness than unregulated systems. Flow regulation particularly affects shallow-water fish species and restricts nutrient transport, reducing downstream fish productivity, especially during winter when discharge is minimal. Therefore, maintaining a minimum environmental flow downstream of hydropower projects such as the Maneri Dam is essential to conserve aquatic biodiversity and sustain key ecological processes.

Acknowledgement: The authors thankfully Principal, Govt PG College Raipur Dehradun, Uttarkashi and Govt. P.G.College Agustyamuni for providing infrastructural facilities for accomplishing this work.

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