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АНАЛІЗ РІЗНОМАНІТНОСТІ ТА МОДЕЛІ РОЗПОДІЛУ РИБИ ВЗДОВЖ ГРАДІЄНТА ВИСОТИ В ПОТОЦІ РАНА, ОКРУГ МАНДІ, ХІМАЧАЛ ПРАДЕШ, ІНДІЯ, З ОСОБЛИВИМ АКЦЕНТОМ НА ЇХ ВЗАЄМОЗВ’ЯЗКУ З ПАРАМЕТРАМИ ВОДИ

Різноманітність іхтіофауни та моделі її розподілу досліджені в потоці Рана, розташованому в районі Манді, Хімачал Прадеш, Індія. Враховуючи значні зміни висот і кліматичних умов у досліджуваному районі, було прийнято стратифікований систематичний підхід до вибірки. Потік був стратифікований на дві зони, вище та вниз за течією, на основі градієнта висоти. Всього було ідентифіковано п’ять видів риб, що представляють чотири роди та два ряди , а саме Cypriniformes і Channiformes. Карпоподібні переважали. Розраховано коефіцієнти кореляції Спірмена між видами риб і вибраними абіотичними параметрами води у потоці. Для оцінки різноманітності іхтіофауни потоку розраховано низку індексів різноманітності, включаючи індекс Сімпсона, індекс різноманітності Сімпсона, індекс різноманітності Шеннона, індекс рівномірності Пілоу та індекс Маргалефа. Значення індексу якості води (WQI) змінювались від 49,65 до 55,14, тобто від «доброї» до «забрудненої». Видове різноманіття виявилося вищим нижче за течією порівняно з верхньою зоною. Подібним чином мікробіотопи вниз за течією також характеризувались вищою видовою різноманітністю іхтіофауни. Встановлено, що низький градієнт висот і повільна течія в місцях нижче за течією створюють умови для накопичення поживних речовин і сприяють більш інтенсивному розвитку риб.

Ключові слова: *потік, різноманітність іхтіофауни, фізико-хімічні параметри, індекси різноманітності, кореляція Спірмена, канонічний кореляційний аналіз (CCA), індекс якості води (WQI).*

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Introduction

Freshwater ecosystems are integral to human well-being as demonstrated by the significance of the fish populations they inhabit reflecting the ecosystem's health and vitality [14]. These ecosystems dispersed across different aquatic habitats showcase diversity influenced by factors like altitude, flow patterns, dissolved oxygen content, substrate makeup, and the presence of riparian zones, which offer essential resources for sustenance and protection [4].

Freshwater environments, despite encompassing less than 1 % of the Earth's surface, harbor more than 40 % of the world's fish species diversity [12], establishing them as vital repositories of varied fauna, where fish play pivotal roles as indicators of ecosystem well-being [28]. Many unique species are confined to headwater streams [21, 29]. Nonetheless, these ecosystems confront substantial and deleterious impacts resulting from climate change and human activities [20].

Hill streams and headwaters are essential in shaping the morphology and hydrology of larger river systems, impacting various abiotic parameters and water availability. As vital components of fluvial ecosystems, streams significantly enrich the diversity of aquatic fauna, including fish. Streams are delineated as narrow to wide corridors where water courses carving channels through landscapes and geological formations. These environments fall within the category of freshwater lotic ecosystems, renowned for their intricate flow dynamics and diverse array of habitats, thus serving as invaluable ecological resources [52].

Several factors influence the habitat preferences of fish in freshwater streams, including fish population dynamics, geomorphology, climate conditions, flow patterns, temperature, dissolved oxygen levels, sediment composition, and pollutant concentrations. The diversity of habitats plays a crucial role in determining the structure and composition of fish communities within stream ecosystems [16, 33]. Habitats with greater diversity tend to support a wider range of species and age groups compared to less complex habitats. Therefore, understanding how stream fish utilize their habitats provides valuable insights into species niches and variations in the availability of specific instream habitat structures. It is essential to integrate fish ecology with the diversity of physical habitats across various spatial scales to comprehend how the habitats influence fish distribution [18].

It is noted [11] that press disturbances, such as mining, logging, and channelization of stream, have notable impacts on fish communities. Specifically, channelization reduces habitat variability, leading to the decline of sensitive fish species and an overall reduction in fish diversity [32]. Further it was emphasized [27] that channelization is a primary cause of stream habitat loss and degradation, posing a threat to the biodiversity of running waters. Additionally, increased severity of channelization results in changes to species composition, altering the stream ecosystem.

The performed investigations [11] have shown the recovery rate of fish communities affected by channelization and found that lotic fish communities were not resilient to press disturbances without mitigation efforts. Species within rock-substrate took significantly longer time to recolonize compared to species within other reproductive guilds.

Moreover, effective restoration of habitats requires identifying relevant habitat features and understanding potential limiting factors [9]. India contributes approximately 7.7 % to the worldwide fish diversity, with 1,668 marine species and 1,027 freshwater species [15, 17]. However, studies on the structure of fish communities and their habitat necessities in Indian streams are scarce, although some investigations have been carried out in the Himalayan area [1, 39, 50].

The state of Himachal Pradesh harbors diverse aquatic ecosystems, including hill streams, rivers, and reservoirs. Exploration of the fish fauna in Himachal Pradesh traces back to the early 19th century with the arrival of European traders and missionaries. Literature review reveals contributions from various researchers in exploring the fish faunal resources across different regions of Himachal Pradesh. Notable contributors include [6, 7, 23, 26, 30, 35, 36, 41, 47, 49]. The descriptions of 81 fish species belonging to 59 genera from Himachal Pradesh are provided in [49], while 106 fish species comprising 58 genera, 19 families, and 8 orders are documented in [48].

The primary objective of current study is to examine the diversity and distribution of fish across varying altitudes in the Rana stream, situated in the Jogindernagar region of the Mandi district, H.P. Furthermore, it seeks to assess the correlation between fish diversity and specific physicochemical parameters of stream water. Through this study, we aim to understand the fish diversity in different habitats and the impact of physicochemical parameters on fish diversity. By doing so, we can offer crucial information for future research on the fish diversity of Himachal Pradesh that will aid in the conservation of fish diversity.

Material and Methods

Study area. The Rana stream, positioned in the Joginder Nagar area of the Mandi district in Himachal Pradesh, India, is characterized by its continuous flow (Figure 1). Its source is in the Bir Billing region of the Kangra district in Himachal Pradesh, and it merges with the Beas River at Banaruawal in the Mandi district, around 27 km away from the Joginder Nagar bus stand. The water from this stream is utilized for various purposes including irrigation and fish farming. Additionally, the Mahseer fish farm in the Joginder Nagar is located on the right bank of this stream. Furthermore, several hydroelectric projects are present along its course.

*Sampling design.*The present study employed a stratified systematic sampling approach. The sampling sites were designated as follows: an upstream location adjacent to Sahib Bandgi Sant Ashram, Jogindernagar, located at a latitude of 31°58'12.70''N and a longitude of 76°46'9.80''E. Downstream locations were identified near Govt. Center Primary School Khuddar, positioned at a latitude of 31°56'21.49''N and a longitude of 76°47'42.48''E, and close to Shiv Temple, Banaun, with a latitude of 31°57'17.39''N and a longitude of

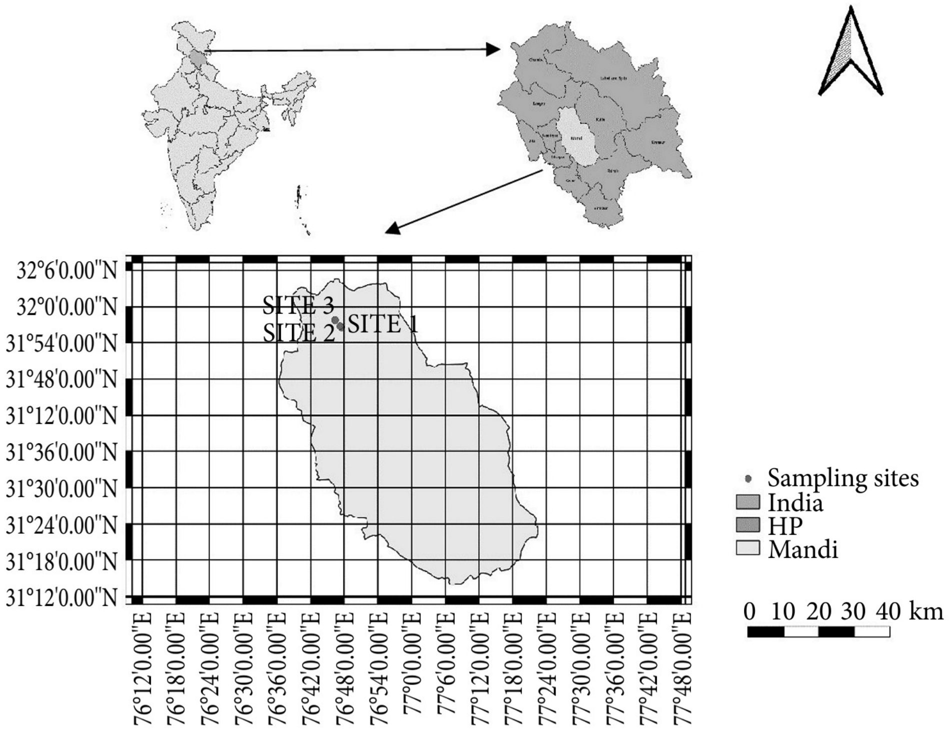

Fig. 1. Map showing the study area of the Rana stream

76°46'42.65"E (Table 1). Within each sampling location, fish were collected from three distinct microhabitats: pool, run, and riffle. All collections were conducted within a 1-kilometer radius of the sampling sites (Figure 2).

Physicochemical parameters of the water. To evaluate the water quality of the Rana stream, we systematically gathered monthly water samples from specific locations along the stream from February 2023 to December 2023. Carefully, we collected samples in sterile 500 ml bottles. We conducted on-site measurements of various abiotic parameters such as electrical conductivity (EC), total dissolved solids (TDS), air temperature, water temperature, pH, and dissolved oxygen (DO) using digital probes. In the laboratory, we conducted as-

Table 1

Location of sampling sites in the Rana stream

Site	Latitude	Longitude	Name of location
Site 1 (Downstream)	31°56'21.49"N	76°47'42.48"E	Near to Govt. Center Primary school Khuddar
Site 2 (Downstream)	31°57'17.39"N	76°46'42.65"E	Near to Shiv temple, Banaun
Site 3 (Upstream)	31°58'12.70"N	76°46'9.80"E	Near to Sahib Bandgi Sant Ashram, Jogindernagar

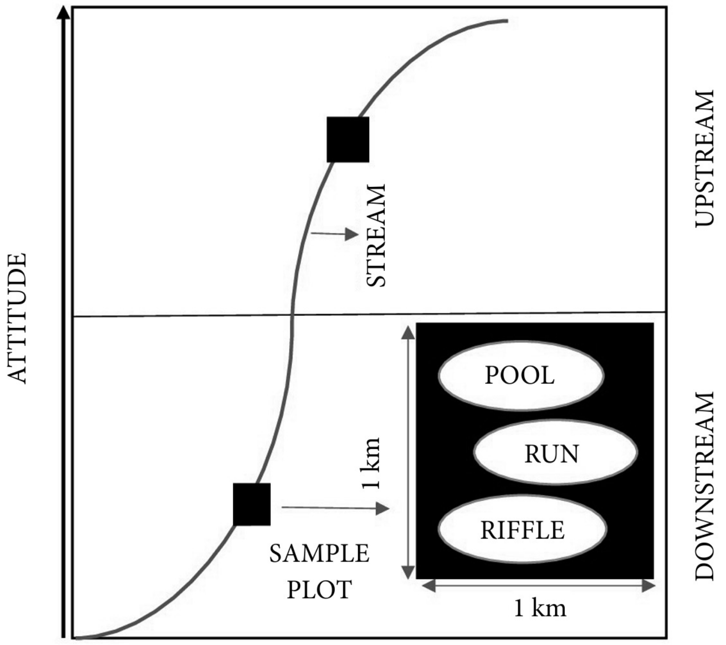

Fig. 2. Sampling design

sessments of total hardness (TH), total alkalinity, phosphates, chlorides, nitrates, and silicates following standardized methodologies outlined by [3].

Fish collection, preservation and identification. For fish collection, we have obtained permission form the Directorate of Fisheries, Himachal Pradesh. Fish specimens were captured using cast nets and gill nets over the period from February 2023 to December 2023. Subsequently, these specimens were immersed in a solution of formaldehyde with the end concentration of 5—10 % and brought to the laboratory for further scientific investigation. The identification of individual fish species was conducted following taxonomic criteria and guidelines outlined in the publications [25, 54].

An analysis of data. Diversity indices were employed to assess species diversity across different altitudinal zones and microhabitats. The Shannon index of diversity (*H'*), Simpson's index (*D*), Simpson's index of diversity (*1-D*), Margalef's index of richness (*Dmg*) and Pielou's index of evenness (*J*) were used to quantify species diversity, evenness, and richness of fish populations. To assess variances between altitudinal zones and microhabitats the Kruskal-Wallis test was carried out. To examine relationship between fish population size and physicochemical parameters, Spearman's correlation analysis was employed. Additionally, Canonical Correspondence Analysis was utilized to elucidate the dispersal of fish species in association with selected physicochemical parameters. The Water quality Index (*WQI*) was used to know the stream water quality.

Results and Discussion

Physicochemical parameters of water. The summary of water physicochemical parameters is given in Table 2. In general, the downstream section of the stream recorded the highest values for all these parameters.

Species composition. During the course of the current study, a sum of 5 fish species (*Barilius vagra* (Hamilton), 1822, *Channa orientalis* Bloch & Schneider, 1801, *Channa punctata* Bloch, 1793, *Tor putitora* Hamilton, 1822, and *Schizothorax richardsonii* Gray, 1832) of four genera, two orders, and two families were documented (Table 3). Among the two orders observed, Cypriniformes emerged as the most dominant order. In the upstream area, only 2 species were observed, namely *Tor putitora* and *Schizothorax richardsonii*. Conversely, in downstream locations, all 5 species were encountered, including *Barilius vagra*, *Channa orientalis*, *Channa punctata*, *Tor putitora*, and *Schizothorax richardsonii*. Furthermore, the distribution of fish species among different microhabitats exhibited variability. All five species were found in microhabitat pools, whereas in the running water microhabitat, except for *Schizothorax richardsonii*, all four species were present. In riffle microhabitats characterized by high turbulence and velocity compared to runs, only three species were observed, namely *Barilius vagra*, *Channa punctata*, and *Channa orientalis*.

Habitat preference of fish. Three major types of fish habitat were identified at the study sites, i.e., pools, runs and riffles. Pools emerged as the most favored habitat, whereas riffles were deemed the least favored habitat for fish.

Both snakeheaded fish i.e. *Channa punctata* and *Channa orientalis* fish recorded from all three habitats (pools, runs and riffles). *Barilius vagra* also inha-

Table 2

List of physicochemical parameters of the Rana stream from (February 2023 to December 2023)

Parameters	Minimum	Maximum	Avg±S.D.
Air temperature (°C)	16.70	36.40	26.97±6.72
Water temperature (°C)	12.10	30.40	22.05±5.62
pH	7.30	9.90	8.50±0.78
TDS (mg/L)	21.00	94.00	55.41±20.45
EC (μs/cm)	106.00	188.00	132.14±24.75
DO (mg/L)	5.60	9.70	7.60±1.21
Alkalinity (mg/L)	16.50	75.00	34.91±19.30
Total hardness (mg/L)	11.00	68.00	37.51±16.83
Chlorides (mg/L)	11.28	48.00	22.84±9.15
Phosphates (mg/L)	0.01	0.83	0.19±0.22
Nitrates (mg/L)	0.01	0.33	0.09±0.09
Silicates (mg/L)	5.38	22.31	12.67±4.62

bited the all three habitats. *Schizothorax richardsonii* exhibited a preference for pools as their habitat, which aligns with the findings reported in [50].

Tor putitora was observed in both pools and runs, consistent with the results of [50], who noted a preference for pool habitats among *Tor* spp. and occasional presence in run habitats. The same results are reported by [26, 46]. The juvenile stage of *Schizothorax richardsonii* specimens was noted in shallow side pools distinguished by comparatively slower water flow and warmer temperatures compared to the deeper mid-stream areas. This finding also corresponds with literature data [50].

Fish diversity across distinct altitudinal zones. An overall diversity index for the study area was recorded as $D = 0.23$, $1\text{-}D = 0.77$, $H' = 1.53$, with $J = 1$ and $Dmg = 0.89$. The downstream areas demonstrated the highest diversity with $D = 0.63$, $1\text{-}D = 0.37$, $H' = 1.54$, $J = 1$, and $Dmg = 0.94$, followed by upstream locations with $D = 0.49$, $1\text{-}D = 0.51$, $H' = 0.69$, $J = 0.44$, and $Dmg = 0.31$ (Table 4). Additionally, the Kruskal-Wallis test found a significant variation between upstream and downstream sampling locations. These variations may be attributed to differences in altitude and climatic conditions between the upstream and downstream areas. Physicochemical parameters such as air temperature, water temperature, alkalinity, pH, TH, phosphates, silicates and nitrates were notably higher in downstream locations compared to upstream locations. Runoff from adjacent crop fields may contribute to higher nutrient concentrations in downstream locations.

During the present study, fish diversity exhibited a variation with altitude. According to [38], fish assemblages are less diverse at higher altitudes due to strong water currents near the origin, whereas they become more diverse towards the merging point of the river where water volume is higher. Additionally, it is stated [19] that fish populations in riverine systems generally display a rise in species diversity as one moves from high to low altitude. Literature data [34] suggest that downstream areas are marked by an open canopy and gentle gradients, factors that help maintain higher water temperatures in streams. Consequently, this leads to increased algal diversity. This higher algal diversity,

Table 3

Composition of freshwater fish species reported from the Rana stream

Species Name	Common Name	Pool	Run	Riffle
Barilius vagra (Hamilton), 1822	Barred barila	+	+	+
Schizothorax richardsonii Gray, 1832	Gray	+	—	—
Tor putitora Hamilton, 1822	Putitor mahseer	+	+	—
Channa punctata Bloch, 1793	Spotted snake headed fish	+	+	+
Channa orientalis Bloch & Schneider, 1801	Smooth breasted snake headed fish	+	+	+

Note. «+» — presence of a species, «—» — absence of a species.

in turn, supports better fish diversity. Thus, the characteristics of downstream locations, as described, may account for the higher quantity of fish species observed in current study.

Fish diversity across diverse microhabitats. Diversity indices of fish varied significantly among different habitats (Table 5). Among the three microhabitats studied, pools exhibited the highest diversity index (*D* = 0.35, *1-D* = 0.65, *H*' = 1.46, *J* = 1, and *Dmg* = 0.92), followed by runs (*D* = 0.83, *1-D* = 0.17, *H'* = 0.99, *J* = 0.68, and *Dmg* = 0.91), and riffles (*D* = 1.2, *1-D* = -0.2, *H'* = 0.63, *J* = 0.43, and *Dmg* = 0.62). The results of the Kruskal-Wallis test indicated notable disparities in fish diversity among different habitats suggesting marked differences between microhabitats.

Top of Form. During the present study, the maximum diversity was reported in pools, followed by runs and riffles. Several factors could contribute to this observation. One possible reason is the lower water current velocity in pools compared to runs and riffles, leading to greater mineral deposition and enhanced algal growth [8]. Increased algal growth can facilitate higher fish growth. Pools, being deeper than surrounding habitats, provide essential refuge for fish, aiding in resting, seeking cover, and escaping predators [5], making them the preferred habitat, which correlates with [50].

Distribution of fish. The observed variations in the distribution of fish species among sampling locations could be attributed to dynamic physicochemical parameters. Parameters such as air temperature, water temperature, alkalinity, pH, TH, phosphates, nitrates, and silicates were notably higher downstre-

Table 4

Calculated fish diversity indices of the Rana stream reported from upstream and downstream locations

Indices	Upstream	Downstream
Simpson's index (*D*)	0.49	0.63
Simpson's index of diversity (*1-D*)	0.51	0.37
Shannon index of diversity (*H'*)	0.69	1.54
Pielou's index of evenness (*J*)	0.44	1
Margalef's index of richness (*Dmg*)	0.31	0.94

Table 5

Calculated fish diversity indices of the Rana stream reported from different habitats

Indices	Pools	Runs	Riffles
Simpson's index (*D*)	0.35	0.83	1.2
Simpson's index of diversity (*1-D*)	0.65	0.17	-0.2
Shannon index of diversity (*H'*)	1.46	0.99	0.63
Pielou's index of evenness (*J*)	1	0.68	0.43
Margalef's index of richness (*Dmg*)	0.92	0.91	0.62

am compared to upstream. Consequently, higher species diversity was observed in the downstream region. Altitude emerges as a key factor, as evidenced by the publication [53], which suggests that altitude notably impacts fish diversity and species richness. This study indicates that a decrease in altitude correlates with an increase in diversity. Additionally, it has been found [45] that stream headwaters harbored fewer species compared to downstream stretches.

The decline in diversity and relative abundance at elevated altitudes could be attributed to factors like fast-flowing currents, lower water temperature, and diminished total outflow towards the sampling site in the upper reaches. This concept is supported by [44], indicating an increase in fish diversity in the lower stretches of streams due to the significant input from numerous small streams, leading to heightened total outflow.

Relationship between fish population size and physicochemical parameters. The Spearman correlation analysis results indicating the relationship between species population size and various physicochemical parameters is given in Table 6. Fish population size exhibited significant positive correlations with pH ($r = 0.586$, $P = 0.01$), total hardness ($r = 0.656$, $P = 0.01$), and silicates ($r = 0.438$, $P = 0.05$). However, there was non-significant correlation observed with EC, TDS, DO and alkalinity.

Significant direct correlations with pH, TH and silicates suggest that an increase in these parameters promotes fish population growth. The optimal pH levels for fish growth typically fall within the range of 6.0 to 9.0, as also supported by [42] indicating that water with pH between 6 and 9 is most conductive to fish growth. In contrast, low pH levels, as noted by [10, 51], can have adverse effects on fish and disrupt the entire ecosystem.

Dissolved oxygen (DO) is a crucial environmental variable affecting aquatic fish populations, with concentrations exceeding 5.00 mg/l being conductive to the proliferation of living organisms. DO is a prominent environmental variable that exerts immediate and direct effects on aquatic fish populations [2]. Although the correlation between DO and fish population size was not significant. Fluctuations in DO levels, particularly associated with rising temperatures, can contribute to fish mortality, as observed in Rewalsar Lake [31].

Silicates play a crucial role in facilitating diatom growth, as diatoms heavily depend on silicon as the main constituent of their shells. The positive correlation between silicates and fish population size underscores the critical role of nutrient availability in establishing a conducive environment for aquatic organisms, especially those occupying the bottom trophic levels of the food chain.

Silicon plays multifaceted roles in diatom physiology. It has been found [37] that silicon facilitates the nutrient uptake and provides defense against the predators [22]. Adequate silicate concentrations support diatom proliferation, which in turn serves as a primary food source for fish, thereby fostering high fish diversity.

On the other hand, fish population size showed an important inverse correlation with water temperature ($r = -0.492$, $P = 0.05$), while exhibiting insignificant inverse correlations with air temperature, nitrates, chlorides and phosphates. This suggests that fish diversity declines with increasing temperature

Table 6

Spearman correlation between fish population size and physicochemical parameters

Indices	pH	EC	TDS	Alkalinity	TH	Water t, °C	DO	Cl^-	PO_4^{3-}	NO_3^-	SiO_3^{2-}	Air t, °C	Population size
pH	1												
EC	0.798**	1											
TDS	0.679**	0.665**	1										
Alkalinity	0.399	0.452*	0.175	1									
TH	0.803**	0.648**	0.826**	0.244	1								
Water t,ºC	-0.567**	-0.484	-0.061	-0.721**	-0.285	1							
DO	0.348	0.505*	0.313	0.643**	0.238	-0.649**	1						
Cl^-	0.319	0.325	0.192	0.097	0.101	-0.39	0.568**	1					
PO_4^{3-}	-0.285	-0.416	-0.353	-0.146	-0.127	0.066	-0.319	0.02	1				
NO_3^-	-0.044	-0.047	-0.36	0.138	-0.191	-0.327	0.003	0.137	0.542**	1			
SiO_3^{2-}	0.800**	0.734**	0.670**	0.301	0.686**	-0.284	0.196	0.228	-0.232	-0.279	1		
Air t, °C	-0.548**	-0.470*	-0.15	-0.626**	-0.321	0.931**	-0.752**	-0.549**	0.086	-0.188	-0.268	1	
Population size	0.586**	0.413	0.391	0.421	0.656**	-0.492	0.135	-0.185	-0.202	-0.193	0.438*	-0.409	1

Note. * Correlation is significant with $P = 0.05$; ** correlation is significant with $P = 0.01$.

and nutrient levels. Elevated water temperature and nutrient concentrations stimulate algal growth, leading to water eutrophication and subsequent algal blooms [24]. Algal blooms can deplete oxygen levels in aquatic ecosystems, resulting in fish mortality due to suffocation. Various impacts on fish mortality, including suffocation, reduced population density, interference with breeding sites and movement, and adverse impacts on fish fitness are reported by [43].

In summary, the current study indicates that rising air temperatures contribute to elevated water temperatures and deteriorating water quality, thereby accelerating the eutrophication process in aquatic environments, which may pose environmental and health challenges for fish populations, which correlates with [40].

Therefore, these physicochemical parameters seem to have influenced the growth of fish, population dynamics and diversity in the Rana stream.

Canonical Corresponding Analysis (CCA). Canonical Correspondence Analysis (CCA) serves as a valuable tool for examining the relationship between physicochemical factors and fish communities. In the CCA plot (Figure 3), the length of arrows represents the importance of variables and indicates their positive or negative correlation with the axes. The longer arrows signify a stronger correlation with the axes.

The eigenvalues for *CCA* Axis 1 and 2 were 0.498 and 0.319, respectively. Water temperature, air temperature, phosphates, and silicates exhibited positive relationships with both Axis 1 & 2. Conversely, EC, alkalinity, and dissolved oxygen were negatively correlated with both axes.

TDS, TH, chlorides, and pH displayed direct relationship with Axis 1 and indirect relation with Axis 2. Conversely, nitrates showed negative association with Axis 1 and positive association with Axis 2.

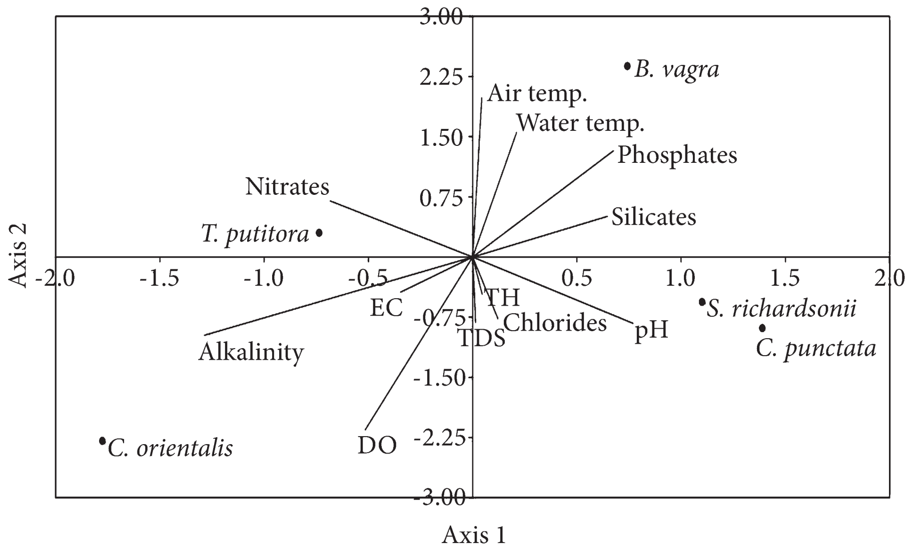

Fig. 3. CCA showing fish species and physicochemical parameters of the Rana stream

The distribution of freshwater fish species such as *Schizothorax richardsonii* and *Channa punctata* showed positive correlations with TDS, TH, chlorides, and pH. *Barilius vagra* exhibited a positive relation with phosphates, silicates, water and air temperature, while *Tor putitora* correlated positively with nitrates. *Channa orientalis* exhibited a direct correlation with EC, DO, and alkalinity.

Water Quality Index. WQI acts as a numerical tool to evaluate water quality. This index provides a mathematical representation of water quality, typically varying from 0 to 100. Lower values, from 0 to 25, signify «excellent» water quality, while values between 25 and 50 indicate «good» quality. Values from 51 to 75 represent «poor» quality, while 76 to 100 denote «very poor» quality. If the index exceeds 100, it suggests that the water is «unsuitable» for consumption [13].

In the case of the Rana stream, the *WQI* ranges from 49.65 to 55.14. This classification places the water quality of the Rana stream within the spectrum of «good» to «poor» based on the *WQI* scale. Various physicochemical parameters, including pH, TDS, EC, DO, alkalinity, TH, chlorides, nitrates, and phosphates, were considered in the calculation of the *WQI* (Table 7).

Conclusion

This study focused on the freshwater fish of the Rana stream in the Mandi district contributing valuable knowledge to the limited understanding of the aquatic fauna of Himachal Pradesh. The primary aim was to establish baseline data on fish diversity to support enhanced conservation and management endeavors.

Table 7

***WQI* of the Rana stream**

Parameters	S_n	W_i	Upstream		Downstream	
			Q_i	W_iQ_i	Q_i	W_iQ_i
pH	8.5	0.12	99.57	11.47	100.32	11.55
TDS (mg/L)	1000	0.00	5.82	0.01	5.26	0.01
EC (ms/cm)	2000	0.00	6.92	0.00	6.30	0.00
DO (mg/L)	5	0.20	164.00	32.11	140.73	27.55
Alkalinity (mg/L)	120	0.01	25.41	0.21	32.77	0.27
TH (mg/L)	300	0.00	11.68	0.04	12.73	0.04
Chlorides (mg/L)	250	0.00	11.36	0.04	6.88	0.03
Phosphates (mg/L)	1.5	0.65	8.85	5.77	24.02	15.68
Nitrates (mg/L)	50	0.02	0.13	0.00	0.23	0.00
WQI				**49.65**		**55.14**

Note. S_n — standards for drinking water [55].

The selected hill stream harbor diverse biotic communities across various microhabitats but face escalating threats from human activities. We documented five fish species from the chosen hill stream. Our observations indicated that most species preferred pool habitats, followed by runs and riffles. Utilizing various diversity indices, we identified deep pools as key habitats contributing to the highest fish species diversity, followed by runs and riffles. Factors such as low gradients, high meandering, elevated water temperature, and nutrient deposition in deep pools downstream were associated with maximal species diversity.

We employed Spearman's correlation method to examine the relationship between abiotic parameters and fish population size, revealing significant direct correlations with pH, total hardness, and silicates, while an inverse correlation was observed with water temperature. Canonical Correspondence Analysis method has also been used.

Assessment of water quality using the Water Quality Index (*WQI*) scale indicated a range from «good» to «poor» quality in the Rana stream, signalling pollution as a potential threat to aquatic fauna and fish diversity in the future.

Given the current state of the Rana stream, we recommend implementing several conservation measures. These include developing a sewage management plan, prohibiting fish killing practices, restricting pesticide usage, and raising awareness among the local community about the importance of conservation efforts to safeguard aquatic ecosystems.

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ANALYSIS OF DIVERSITY AND DISTRIBUTIONAL PATTERN OF FISH ALONG AN ALTITUDINAL GRADIENT IN THE RANA STREAM, MANDI DISTRICT, HIMACHAL PRADESH, INDIA WITH SPECIAL FOCUS ON THEIR RELATIONSHIP WITH AQUATIC PARAMETERS

The fish fauna diversity and distribution patterns were investigated in the Rana stream situated in the Mandi district, Himachal Pradesh. Given the considerable variations in altitude and climatic conditions within the study area, a stratified systematic sampling approach was adopted. The stream was stratified into two zones, upstream and downstream, based on the altitudinal gradient. A total of five fish species were identified, representing 4 genera and 2 orders, namely Cypriniformes and Channiformes. Cypriniformes emerged as the predominant order between the two. The study also examined the Spearman correlation between fish species and selected abiotic parameters of stream water. Several diversity indices, including Simpson's index, Simpson's diversity index, the Shannon index of diversity, Pielou's evenness index, and Margalef's richness index, were employed to evaluate the stream diversity. The Water Quality Index (*WQI*) values varied from 49.65 to 55.14, representing that water quality spanning from «good» to «poor». Species diversity was found to be higher in the downstream altitudinal zone compared to the upstream zone. Similarly, microhabitat pools exhibited greater species diversity. During the present study, we have found that the low gradient and slow current velocity in downstream locations leading to increased nutrient deposition in deep pools thereby favoured higher species abundance.

Keywords: *stream, fish diversity, physicochemical parameters, diversity indices, Spearman correlation, Canonical Corresponding Analysis (CCA), Water Quality Index (WQI).*