# Fish Diversity in Relation to Water Quality, District Dehradun, Uttarakhand, India



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# Fish Diversity in Relation to Water Quality, District Dehradun, Uttarakhand, India

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## ABSTRACT

Fish diversity in relation to water quality of Doon Valley was examined for a period of two years (March 2010–February 2012) at 20 sampling stations set of 5 rivers (Baldi, Song, Suswa, Tons and Asan) in East and West. A total of 56 species were recorded during the present investigation. The Cyprinid family was dominant in the present study. The 15 physical and chemical water quality parameters were undertaken to analyze the water quality. Pearson Product Moment Coefficient of Correlation (PPMCC) was used to study the relation of fish diversity with various water quality parameters. The 54 fish species were recorded from East and 43 from the West, all have shown strong '+ve', strong '–ve', moderate '+ve', moderate '–ve', weak '+ve', weak '–ve' and none relationship to 14 water quality parameters, pH being such a parameter which exhibited neither type of correlation in East or West. From amongst the chemical parameters, BOD has been found to be a parameter of 1$^{st}$ rank which showed +ve correlation with maximum number of species.


**Keywords** Fish diversity, Water quality, Doon Valley, Pearson Product Moment Coefficient of Correlation (PPMCC).

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## INTRODUCTION

Water quality is ever instrumental in sustaining the aquatic life including the vulnerable fish diversity. The assessment of water quality and deriving conclusions about the diversity and distribution of fishery wealth has been another field of exploration likened by research workers (Patela and Vaghanib 2015). Ecological applications of multivariate statistics have expanded tremendously (Gauch 1982), using various methods to observe the aspects like species association analyses, species area relationships, analysis of fish distribution and in defining fish assemblages. Distributions of fishes have been linked statistically to individual water-quality variables (Hawkes et al. 1986).

Rivers and other water bodies are facing large number of environmental problems throughout the world which are largely associated with anthropogenic activities in their catchment areas. The adverse effects of human activities have resulted in degradation of aquatic ecosystem which ultimately alter the structure and function of water biota. This is more critical in developing countries (Khanna and Faouzia 2013). Fish is sensitive to changes in water chemistry due to different anthropogenic activities and its responses to environmental disturbances. Fish has also been identified as suitable for biological assessment due to its easy identification and economic value (Gaston 2000). Fish have been regarded as an effective biological indicator of environmental quality and anthropogenic stress in aquatic ecosystems not only because of its iconic value, but also because of sensitivity to subtle environmental changes and represents a wide range of tolerance at community level (Irigolen et al. 2004). Studies related with fish fauna

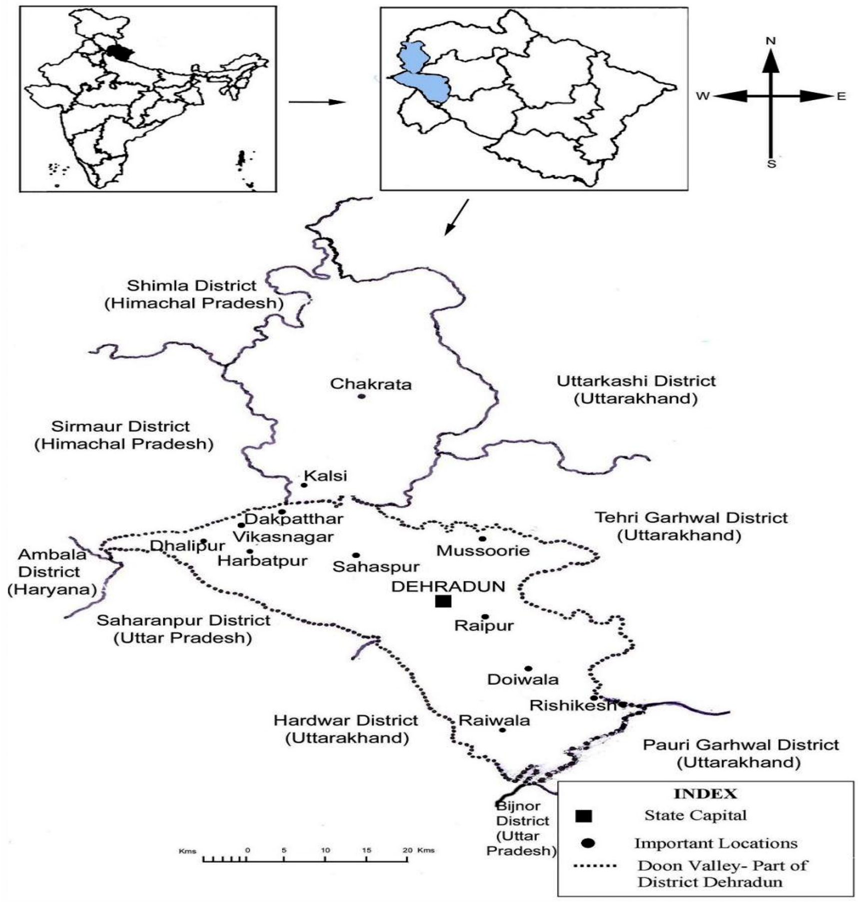


**Fig. 1.** Location of Doon Valley.

and taxonomic works have been carried out in Doon Valley by Gupta and Rana (2009 a, b, c, d), Rana and Gupta (2017a), Rana et al. (2017).

Water pollution makes water unsuitable for drinking, recreation, agriculture and industry that eventually also diminishes the aesthetic quality of water bodies. Even more seriously, when contaminated water destroys aquatic life and reduces its reproductive abilities, it eventually menaces human health. In recent years an easier and simpler approach based on statistical correlation, has been developed using mathematical relationship for comparison of physico-chemical parameters. Extensive research has been carried out on statistical analysis to assess the surface water quality. Statistical analysis of physico-chemical parameters of water has been reported from the different parts of India (Shah et al. 2007, Mulla et al. 2007, Sharma et al. 2009, Bhandari and Nayal 2008, Joshi et al. 2009, Trivedi et al. 2009, Kumar and Sinha 2010). In Doon Valley use of multivariate statistical tools like Pearson Product Moment Coefficient of Correlation (PPMCC), Factor Analysis (FA) and Principal Component Analysis (PCA) on fish and water quality related studies has been attempted (Rana and Bhatt 2014, Rana and Gupta 2016, 2017b, c).

Considering the reason mentioned above, the present study was aimed to observe the environmental dynamics by the correlation study between the fish community and the water quality variables of Doon Valley, District Dehradun, Uttarakhand.

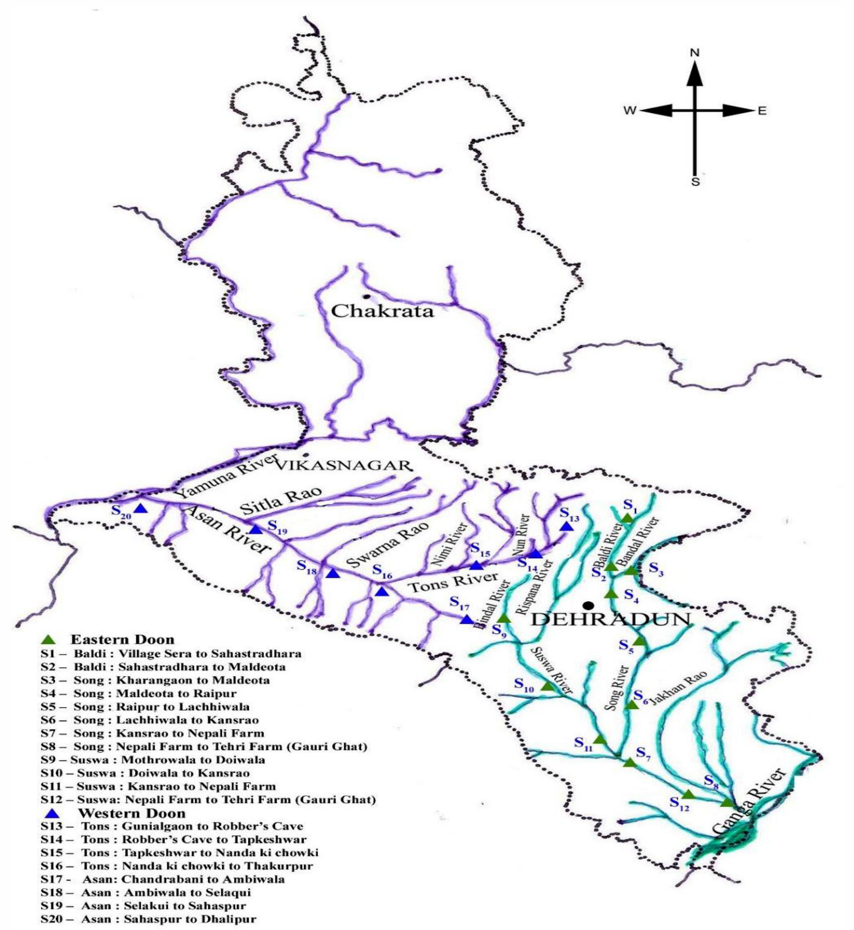


**Fig. 2.** Location of the sampling sites at Doon Valley.

## MATERIALS AND METHODS

Doon Valley, part of District Dehradun (latitude 29°58´ and 30°32´ N and longitude 77°35´ and 78°20´ E) (Fig. 1) comprises of 2 main river basins, namely, the Ganga and the Yamuna river basin. The present study was carried out on these two river systems comprizing of five main rivers i.e., Baldi, Song, Suswa, Tons and Asan (Fig. 2). The climate of the area varies from humid, moist sub-tropical in the Southern part to temperate in the Northern mountainous region with wide temperature range varying from 4.40–35.10°C during the study period. The annual rainfall is highly variable and is mainly controlled by the orography, 82–87% of the annual rainfall occurs under the influence of the South–West monsoon. Winter rains were prevalent during December–March, accounting for about 8% of the total annual rainfall. Sandy loam, sandy clay, coarse sand, silty clay loam, silty loam, sand and clay types are the chief soil types of Doon Valley.

Sampling for fish species and water quality parameters was periodically done for a period of 24 months (March 2010–February 2012) at the 20 sampled stations established along the rivers mentioned above (Fig. 2).

Each river was divided into stretches along its length, according to altitudinal variations to adjudge the spatial and temporal interrelationships. Each stretch covering an approximate distance of about

4–7 km, was thus established as sampling sites. Fish samples were collected by employing standard gears, using variety of fishing nets of varying mesh sizes–gill nets, cast nets, drag nets with the help of trained fishermen on the sampling in the Eastern and Western part of Doon Valley, respectively (Fig. 2). Fish samples were preserved in 4% formalin and bought to the laboratory for routine identification, meristic and morphometric analyses under the light of available standard literature and revisionary works (Day 1878, Jayaram 1981, 1999, Talwar and Jhingran 1991, Vishawanath et al. 2007, Nelson et al. 2016).

The estimation of physical parameters like Depth (D), Width (W), Water Velocity (WV), Air Temperature (AT), Water Temperature (WT) and chemical parameters like Dissolved Oxygen (DO) in mg/l, Carbon dioxide ($CO_2$) in mg/l and pH were firstly analyzed in the field with the help of field water and soil analysis kit. Secondly, the parameters which could not be analyzed in the field viz., Hardness (Hd) in mg/l, Alkalinity (Alk) in mg/l, Turbidity (Turb) in Jackson Turbidity Unit, Biological Oxygen Demand (BOD) in ppm, Nitrates (N) in ppm, Phosphates (P) in ppm and Total Dissolved Solids (TDS) in ppm were analyzed in the laboratory by following standard methods (Trivedy and Goel 1984, APHA et al. 2012).

Simultaneously, water samples were also submitted to the Central laboratory of Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun and Central Pollution Control Board (CPCB), Dehradun for verifying the data procured / analyzed in the field / laboratory before reaching to any final conclusion.

The correlation coefficient analysis (PPMCC) between 15 water quality variables and fish species

**Table 1**. Pearson Product Moment Coefficient of Correlation computed between fish species and physico-chemical environmental variables for East. **Correlation significant at 0.01 level (2–tailed), *Correlation significant at 0.05 level (2–tailed). D=Depth, W=Width, WV=Water Velocity, AT=Air Temperature, WT=Water Temperature, DO = Dissolved Oxygen, $CO_2$ = Carbon Dioxide, Hd = Hardness, Alk = Alkalinity, Turb = Turbidity, BOD = Biological Oxygen Demand, N = Nitrates, P=Phosphates and (TDS) = Total Dissolved Solids.

| Sl. No. | Fish species | D | W | AT | WT | WV | DO | $CO_2$ | pH |
|---|---|---|---|---|---|---|---|---|---|
| 1. | *Cyprinus carpio* | 0.149* | 0.328** | 0.195** | 0.044 | 0.116* | − 0.179** | 0.151* | − 0.126* |
| 2. | *Puntius chola* | 0.361** | 0.522** | 0.145* | 0.214** | − 0.189** | − 0.214** | 0.027 | 0.139* |
| 3. | *Pethia conchonius* | 0.390** | 0.360** | 0.269** | 0.364** | − 0.338** | 0.339** | 0.110 | 0.035 |
| 4. | *Puntius sarana* | 0.358** | 0.512** | 0.134** | 0.202* | − 0.170** | 0.217** | 0.036 | 0.142* |
| 5. | *Puntius sophore* | 0.357** | 0.507** | 0.142* | 0.215** | − 0.189** | − 0.219** | 0.033 | 0.140* |
| 6. | *Pethia ticto* | 0.393** | 0.370** | 0.277** | 0.373** | − 0.326** | − 0.342** | 0.117* | 0.034 |
| 7. | *Puntius terio* | 0.072 | −0.106 | 0.064 | 0.139* | − 0.055 | − 0.111 | 0.135* | 0.009 |
| 8. | *Chagunius chagunio* | 0.311** | 0.086 | 0.039** | 0.332** | − 0.166** | − 0.264** | 0.243** | −0.084 |
| 9. | *Shizothorax richardsonii* | −0.658** | −0.346** | − 0.482** | − 0.369** | 0.237** | 0.619** | − 0.296** | 0.259** |
| 10. | *Shizothorachthys progastus* | −0.537** | −0.318** | − 0.349** | − 0.344** | 0.297** | 0.431** | − 0.170** | 0.096 |
| 11. | *Labeo dyocheilus* | 0.107 | 0.045 | − 0.114 | −0.233** | 0.016 | 0.172** | − 0.119* | 0.059 |
| 12. | *Labeo pangusia* | 0.087 | −0.004 | 0.015 | − 0.159** | 0.075 | 0.030 | 0.067 | 0.014 |
| 13. | *Bangana dero* | 0.248** | 0.048 | 0.360** | 0.202** | 0.191** | − 0.350** | 0.419** | −0.116* |
| 14. | *Aspidoparia jaya* | 0.394** | 0.292** | 0.056 | 0.222** | − 0.481** | − 0.119* | −0.220** | −0.080 |
| 15. | *Cabdio morar* | 0.265** | 0.232** | 0.239** | 0.299** | − 0.201** | − 0.368** | 0.126* | − 0.218** |

**Table 1.** Continued.

| Sl. No. | Fish species | D | WAT | WT | WV | DO | $CO_2$ | pH | |
|---|---|---|---|---|---|---|---|---|---|
| 16. | *Osparius barna* | 0.459** | 0.413** | 0.161** | 0.289** | −0.390** | −0.261** | −0.005 | 0.132* |
| 17. | *Barilius bendelisis* | 0.092 | 0.070 | 0.004 | 0.109 | −0.420** | 0.119* | −0.177** | 0.220** |
| 18. | *Barilius vagra* | 0.213** | 0.106 | 0.199** | 0.231** | −0.264** | −0.141* | 0.104 | 0.072 |
| 19. | *Osparius tileo* | 0.197** | 0.568** | 0.100 | 0.038 | −0.094 | −0.068 | −0.010 | 0.001 |
| 20. | *Danio rerio* | 0.361** | 0.522** | 0.145* | 0.214** | −0.189** | −0.214** | 0.027 | 0.139* |
| 21. | *Devario devario* | 0.393** | 0.370** | 0.277** | 0.373** | −0.326** | −0.342** | 0.117* | 0.034 |
| 22. | *Esomus danrica* | 0.357** | 0.507** | 0.142* | 0.215** | −0.189** | −0.219** | 0.033 | 0.140* |
| 23. | *Raiamas bola* | 0.178** | 0.454** | 0.119* | 0.022 | 0.061 | −0.155** | 0.111 | −0.041 |
| 24. | *Rasbora daniconius* | 0.393** | 0.370** | 0.277** | 0.373** | −0.326** | −0.342** | 0.117* | 0.034 |
| 25. | *Crossocheilus latius* | 0.238** | 0.063 | 0.135* | 0.051 | −0.081 | −0.015 | 0.124* | −0.009 |
| 26. | *Garra gotyla* | 0.138* | 0.086 | 0.001 | − 0.045 | −0.094 | 0.187** | − 0.014 | 0.115 |
| 27. | *Tor putitora* | 0.384** | 0.447** | 0.080 | −0.039 | −0.201** | 0.089 | − 0.010 | 0.052 |
| 28. | *Tor tor* | 0.293** | 0.256** | 0.183** | 0.117** | − 0.120* | −0.068 | 0.023 | − 0.061 |
| 29. | *Tor chelynoides* | −0.670** | −0.363** | −0.449** | −0.339** | 0.227** | 0.605** | −0.282** | 0.234** |
| 30. | *Lepidocephalichthys guntea* | 0.055 | 0.249** | 0.029 | 0.202** | −0.463** | −0.028 | − 0.198** | 0.192** |
| 31. | *Lepidocephalichthys annandalei* | 0.062 | − 0.200** | −0.006 | 0.118* | −0.177** | 0.011 | − 0.091 | 0.084** |
| 32. | *Acanthocobitis botia* | 0.099 | 0.247** | 0.030 | 0.202** | −0.508** | −0.054 | − 0.215** | 0.138** |
| 33. | *Paraschistura montana* | − 0.680** | − 0.359** | −0.477** | − 0.364** | 0.086 | 0.647** | − 0.340** | 0.222** |
| 34. | *Schistura rupecula* | −0.637** | − 0.292** | −0.396** | − 0.293** | 0.169** | 0.510** | −0.214** | 0.096** |
| 35. | *Schistura savona* | −0.455* | − 0.311** | −0.404** | − 0.362** | 0.199** | 0.548** | − 0.311** | 0.266** |
| 36. | *Amblyceps mangois* | 0.330** | 0.616** | 0.256** | 0.296** | −0.214** | −0.325** | 0.080 | −0.023 |
| 37. | *Glyptothorax pectinopterus* | − 0.334** | −0.160** | −0.175** | − 0.192** | 0.137* | 0.368** | − 0.078 | 0.060 |
| 38. | *Glyptothorax saisii* | − 0.381** | − 0.278** | −0.273** | − 0.280** | 0.224** | 0.392** | − 0.192** | 0.120* |
| 39. | *Glyptothorax telchitta* | 0.072 | − 0.106 | 0.064 | 0.139* | −0.005 | −0.111 | 0.135* | 0.009 |
| 40. | *Clarias batrachus* | 0.392** | 0.654** | 0.195** | 0.155** | −0.069 | −0.291** | 0.090 | 0.079 |
| 41. | *Heteropneustes fossilis* | 0.356** | 0.633** | 0.219** | 0.245** | −0.176** | −0.302** | 0.065 | 0.021 |
| 42. | *Mystus tengara* | 0.387** | 0.736** | 0.330** | 0.287** | −0.224** | 0.305** | 0.082 | − 0.190** |
| 43. | *Mystus bleekeri* | 0.425** | 0.744** | 0.244** | 0.121* | −0.005 | −0.261** | 0.172** | − 0.077 |

**Table 1.** Continued.

| Sl. No. | Fish species | D | W | AT | WT | WV | DO | $CO_2$ | pH |
|---|---|---|---|---|---|---|---|---|---|
| 44. | *Xenentodon cancila* | 0.442** | 0.472** | 0.264** | 0.337** | −0.271** | − 0.302** | 0.076 | 0.002 |
| 45. | *Macrognathus pancalus* | 0.373** | 0.580** | 0.187** | 0.310** | −0.364** | −0.259** | 0.104 | 0.031 |
| 46. | *Mastacembelus armatus* | 0.358** | 0.322** | 0.293** | 0.378** | −0.321** | −0.374** | 0.095 | − 0.023 |
| 47. | *Badis badis* | 0.353** | 0.389** | 0.182** | 0.299** | −0.395** | −0.233** | −0.042 | 0.10 |
| 48. | *Trichogaster fasciata* | 0.103 | 0.227** | 0.051 | 0.043** | −0.210** | −0.132* | 0.038 | 0.088 |
| 49. | *Trichogaster lalius* | 0.089 | − 0.153** | 0.029 | 0.221** | −0.170** | −0.137* | 0.038 | 0.117* |
| 50. | *Trichogaster labiosa* | 0.119* | − 0.249** | 0.052 | 0.265** | −0.230** | −0.143* | 0.043 | 0.082 |
| 51. | *Channa punctata* | 0.366** | 0.302** | 0.235** | 0.320** | −0.297** | −0.255** | 0.061 | 0.062 |
| 52. | *Channa gachua* | 0.383** | 0.427** | 0.283** | 0.288** | −0.175** | −0.397** | 0.240** | 0.040 |
| 53. | *Channa marulius* | 0.280** | 0.247** | 0.197** | 0.221** | −0.106 | −0.310** | 0.220** | 0.141* |
| 54. | *Channa harcourtbutleri* | 0.113 | −0.165** | 0.067 | 0.227** | −0.134* | −0.154** | 0.103 | 0.062 |

**Table 1**. Continued.

| Sl. No. | Fish species | Hd | Alk | Turb | BOD | N | P | TDS |
|---|---|---|---|---|---|---|---|---|
| 1. | *Cyprinus carpio* | −0.119* | −0.096 | 0.200** | −0.084 | −0.102 | − 0.044 | − 0.081 |
| 2. | *Puntius chola* | −0.201** | 0.269** | − 0.048 | 0.420** | 0.260** | 0.246** | − 0.184** |
| 3. | *Pethia conchonius* | − 0.237** | 0.261** | − 0.023 | 0.628** | 0.469** | 0.360** | − 0.270** |
| 4. | *Puntius sarana* | −0.200** | 0.256** | − 0.039 | 0.437** | 0.244** | 0.248** | − 0.184** |
| 5. | *Puntius sophore* | − 0.193** | 0.262** | − 0.046 | 0.445** | 0.261** | 0.247** | − 0.177** |
| 6. | *Pethia ticto* | −0.236** | 0.263** | − 0.015 | 0.623** | 0.455** | 0.352** | − 0.268** |
| 7. | *Puntius terio* | − 0.047 | 0.124* | 0.068 | 0.533** | 0.181** | 0.205** | − 0.021 |
| 8. | *Chagunius chagunio* | 0.168** | 0.238** | 0.120* | 0.556** | 0.378** | 0.469** | − 0.198** |
| 9. | *Shizothorax richardsonii* | 0.525** | 0.250** | − 0.164** | 0.334** | 0.375** | − 0.413** | 0.506** |
| 10. | *Shizothorachthys progastus* | 0.235** | −0.078 | − 0.027 | −0.287** | −0.331** | − 0.327** | 0.249** |
| 11. | *Labeo dyocheilus* | − 0.337 | −0.248** | − 0.054 | −0.164** | −0.189** | − 0.148* | − 0.362** |
| 12. | *Labeo pangusia* | − 0.291** | −0.240** | 0.085 | 0.009 | − 0.141* | 0.004 | − 0.327** |
| 13. | *Bangana dero* | − 0.201** | 0.059 | 0.348** | 0.237** | 0.149* | 0.340** | − 0.222** |
| 14. | *Aspidoparia jaya* | −0.325** | − 0.029 | − 0.236** | 0.152** | 0.212** | − 0.026 | − 0.358** |
| 15. | *Cabdio morar* | − 0.079 | 0.013 | 0.020 | 0.212** | 0.179** | 0.032 | 0.049 |
| 16. | *Osparius barna* | −0.286** | 0.210** | − 0.178** | 0.551** | 0.435** | 0.305** | −0.321** |
| 17. | *Barilius bendelisis* | 0.020 | 0.531** | − 0.228** | 0.399** | 0.452** | 0.193** | − 0.077** |
| 18. | *Barilius vagra* | − 0.080 | 0.371** | − 0.003 | 0.536** | 0.470** | 0.412** | − 0.147** |
| 19. | *Osparius tileo* | − 0.152* | 0.041 | − 0.029 | −0.126* | − 0.009 | − 0.051 | − 0.134** |
| 20. | *Danio rerio* | − 0.201** | 0.269** | − 0.048 | 0.420** | 0.260** | 0.246** | − 0.184** |
| 21. | *Devario devario* | −0.236** | 0.263** | − 0.015 | 0.623** | 0.455* | 0.352** | − 0.268** |
| 22. | *Esomus danrica* | − 0.193** | 0.262** | − 0.046 | 0.445** | 0.261** | 0.247** | − 0.177** |
| 23. | *Raiamas bola* | 0.129* | − 0.039 | 0.127* | −0.105 | −0.117** | −0.034 | − 0.102 |
| 24. | *Rasbora daniconius* | −0.236** | 0.263** | − 0.015 | 0.623** | 0.455** | 0.352** | − 0.268** |
| 25. | *Crossocheilus latius* | −0.087 | 0.146* | 0.065 | 0.394** | 0.222** | 0.255** | − 0.108 |
| 26. | *Garra gotyla* | −0.120* | 0.170** | − 0.043 | 0.348** | 0.153** | 0.145* | 0.165** |

**Table 1**. Continued.

| Sl. No. | Fish species | Hd | Alk | Turb | BOD | N | P | TDS |
|---|---|---|---|---|---|---|---|---|
| 27. | *Tor putitora* | −0.196** | 0.244** | − 0.049 | 0.172** | 0.112 | 0.180** | − 0.246** |
| 28. | *Tor tor* | − 0.234** | 0.005 | − 0.017 | 0.042 | 0.049 | 0.099 | − 0.215** |
| 29. | *Tor chelynoides* | 0.458** | 0.230** | − 0.152** | −0.315** | −0.304** | − 0.356** | 0.491** |
| 30. | *Lepidocephalichthys guntea* | − 0.079 | 0.358** | − 0.257** | 0.293** | 0.483** | 0.108 | − 0.174** |
| 31. | *Lepidocephalichthys annandalei* | − 0.062 | 0.112 | − 0.115 | 0.244** | 0.380** | 0.237** | − 0.083 |
| 32. | *Acanthocobitis botia* | − 0.156** | 0.289** | − 0.276** | 0.329** | 0.482** | 0.100 | − 0.224** |
| 33. | *Paraschistura montana* | 0.540** | 0.345** | − 0.217** | −0.310** | −0.240** | − 0.242** | 0.529** |
| 34. | *Schistura rupecula* | 0.672** | 0.344** | − 0.126* | −0.313** | −0.277** | − 0.402** | 0.760** |
| 35. | *Schistura savona* | 0.087 | −0.067 | − 0.163** | −0.287** | −0.301** | − 0.256** | 0.000 |
| 36. | *Amblyceps mangois* | − 0.237** | 0.186** | 0.011 | 0.304** | 0.196** | 0.130* | − 0.227** |
| 37. | *Glyptothorax pectinop-terus* | 0.097 | 0.077 | 0.002 | − 0.133* | −0.180** | − 0.197** | 0.034 |
| 38. | *Glyptothorax saisii* | − 0.004 | −0.202** | − 0.055 | 0.249** | −0.288** | − 0.303** | − 0.058 |
| 39. | *Glyptothorax telchitta* | − 0.047 | 0.124* | 0.068 | 0.533** | 0.181** | 0.205** | − 0.021 |
| 40. | *Clarias batrachus* | − 0.233** | 0.148* | 0.055 | 0.209** | 0.144** | 0.114 | − 0.220** |
| 41. | *Heteropneustes fossilis* | − 0.226** | 0.169** | 0.001 | 0.316** | 0.206** | 0.115 | − 0.218** |
| 42. | *Mystus tengara* | 0.226** | 0.023 | 0.063 | −0.044 | −0.005 | 0.024 | − 0.222** |
| 43. | *Mystus bleekeri* | − 0.101 | 0.092 | 0.132* | −0.049 | −0.090 | − 0.006 | − 0.024 |
| 44. | *Xenentodon cancila* | −0.280** | 0.194** | − 0.007 | 0.536** | 0.374** | 0.267** | − 0.288** |
| 45. | *Macrognathus pancalus* | −0.283** | 0.208** | − 0.151* | 0.353** | 0.287** | 0.130* | − 0.290** |
| 46. | *Mastacembelus armatus* | −0.217** | 0.239** | − 0.006 | 0.542** | 0.443** | 0.298** | − 0.260** |
| 47. | *Badis badis* | − 0.258** | 0.275** | − 0.156** | 0.530** | 0.456** | 0.285** | − 0.283** |
| 48. | *Trichogaster fasciata* | −0.058 | 0.209** | − 0.061 | 0.786** | 0.486** | 0.377** | − 0.084 |
| 49. | *Trichogaster lalius* | − 0.033 | 0.196** | − 0.053 | 0.818** | 0.375** | 0.292** | − 0.049 |
| 50. | *Trichogaster labiosa* | −0.050 | 0.266** | − 0.065 | 0.825** | 0.517** | 0.393** | − 0.092 |
| 51. | *Channa punctata* | − 0.201** | 0.291** | − 0.044 | 0.638** | 0.479** | 0.356** | − 0.242** |
| 52. | *Channa gachua* | − 0.229** | 0.242** | 0.090 | 0.522** | 0.311** | 0.336** | − 0.242** |
| 53. | *Channa marulius* | − 0.162** | 0.260** | 0.041 | 0.630** | 0.350** | 0.358** | − 0.172** |
| 54. | *Channa harcourtbutleri* | −0.034 | 0.212** | 0.006 | 0.874** | 0.379** | 0.323** | − 0.047 |

was done separately, for Eastern and Western Doon, using the station–wise and month–wise data regarding number of individuals of fish species and water quality parameters. The results were obtained in the form of correlation matrix (Tables 1 and 2) with correlation values (r) indicating the strength of coherence between fish species and water quality variables.

## RESULTS

The results of Pearson Product Moment Coefficient of Correlation (PPMCC) (Tables 1–2) have categorically revealed 7 correlation modes for both East and West viz., strong '+ve' ($r = \geq + 0.50$), strong '–ve' ($r = \geq - 0.50$), moderate ' + ve' ($r = \geq + 0.30$), moderate '–ve' ($r = \geq -0.30$), weak ' + ve' ($r = \geq + 0.10$), weak '–ve' ($r = \geq - 0.10$)' and none ($r = 0.0$) to have been judged at 2 levels of significance i.e., $p \geq 0.05$ and 0.01. 54 species recorded from East and 43 from the West have been evaluated only with reference to those parameters with which they have strong +ve/ moderate +ve or strong –ve/ moderate –ve relationships ; the weak or none relationships left out of consideration. Weak or none correlations will be referred in the discussions to follow whenever / wherever deemed essential.

Out of 15 water quality parameters, pH has been such a parameter which exhibited neither strong +ve / moderate +ve nor strong –ve / moderate –ve type of correlation for the streams of East or West, but a perusal of Tables 1 and 2 will reveal that it has weak +ve and weak –ve correlation with fish species. This is explainable on the basis of the fact that pH alone

**Table 2**. Pearson Product Moment Coefficient of Correlation computed between fish species and physico-chemical environmental variables for West. **Correlation significant at 0.01 level (2–tailed), *Correlation significant at 0.05 level (2–tailed). D=Depth, W=Width, WV=Water Velocity, AT=Air Temperature, WT=Water Temperature, DO = Dissolved Oxygen, $CO_2$ = Carbon Dioxide, Hd = Hardness, Alk = Alkalinity, Turb = Turbidity, BOD = Biological Oxygen Demand, N = Nitrates, P=Phosphates and (TDS) = Total Dissolved Solids.

| Sl. No. | Fish species | D | W | AT | WT | WV | DO | $CO_2$ | pH |
|---|---|---|---|---|---|---|---|---|---|
| 1. | *Puntius chola* | 0.488** | 0.744** | − 0.164* | 0.156* | − 0.339** | 0.031 | − 0.145* | 0.009 |
| 2. | *Pethia conchonius* | 0.511** | 0.760** | − 0.135 | 0.235** | −0.302** | − 0.004 | − 0.193** | 0.101 |
| 3. | *Puntius sarana* | 0.538** | 0.768** | −0.146* | 0.169* | −0.295** | −0.005 | − 0.106 | 0.028 |
| 4. | *Puntius sophore* | 0.495** | 0.748** | −0.156* | 0.173* | 0.324** | 0.016 | − 0.129 | 0.014 |
| 5. | *Pethia ticto* | 0.517** | 0.757** | − 0.142* | 0.224** | − 0.298** | − 0.011 | − 0.190** | 0.125 |
| 6. | *Chagunius chagunio* | 0.725** | 0.777** | 0.046 | 0.265** | −0.051 | −0.204** | 0.162* | 0.044 |
| 7. | *Shizothorax richardsonii* | −0.340** | −0.448** | − 0.074 | − 0.245** | 0.169* | 0.259** | − 0.108 | 0.020 |
| 8. | *Labeo dyocheilus* | 0.510** | 0.348** | 0.306** | 0.174* | 0.366** | −0.522** | 0.445** | 0.145 |
| 9. | *Bangana dero* | −0.249** | −0.137 | −0.177* | − 0.105 | −0.265** | 0.399** | 0.266** | − 0.181 |
| 10. | *Aspidoparia jaya* | 0.488 | 0.365 | − 0.046 | 0.050 | − 0.084 | −0.022 | 0.014 | − 0.100 |
| 11. | *Cabdio morar* | 0.690** | 0.786** | 0.133 | 0.264** | − 0.045 | −0.246** | 0.232** | −0.013 |
| 12. | *Osparius barna* | 0.770** | 0.936 | 0.090 | 0.359** | −0.170* | −0.304** | 0.167* | 0.003 |
| 13. | *Barilius bendelisis* | − 0.169* | 0.176* | − 0.319** | − 0.012 | − 0.436** | 0.441** | − 0.404** | −0.040 |
| 14. | *Barilius vagra* | − 0.128 | 0.159* | 0.396** | − 0.063 | 0.472** | 0.509** | − 0.503** | − 0.028 |
| 15. | *Barilius shacra* | 0.471** | 0.581** | 0.034 | 0.262** | − 0.127 | − 0.109 | 0.059 | 0.112 |
| 16. | *Danio rerio* | 0.488** | 0.744** | − 0.164* | 0.156* | −0.339** | 0.031 | − 0.145* | 0.009 |
| 17. | *Devario devario* | 0.570** | 0.757** | −0.142* | 0.224** | − 0.298** | −0.011 | − 0.190** | 0.125 |
| 18. | *Esomus danrica* | 0.495** | 0.748** | − 0.156* | 0.173* | −0.324** | 0.016 | − 0.129 | 0.014 |
| 19. | *Rasbora daniconius* | 0.570** | 0.757** | −0.142** | 0.224** | − 0.298** | −0.011 | 0.190** | 0.125 |
| 20. | *Crossocheilus latius* | − 0.241** | − 0.290** | −0.210** | − 0.354** | 0.045 | 0.293** | − 0.226** | 0.042 |
| 21. | *Garra gotyla* | − 0.336** | − 0.309** | − 0.316** | − 0.379** | −0.120 | 0.436** | − 0.352** | 0.044 |
| 22. | *Tor putitora* | − 0.014 | 0.256** | −0.174* | 0.087 | − 0.301** | 0.279** | − 0.268** | − 0.091 |
| 23. | *Tor tor* | 0.498** | 0.736** | − 0.022 | 0.336** | −0.235** | −0.147* | 0.013 | − 0.035 |
| 24. | *Tor chelynoides* | − 0.399** | − 0.444** | − 0.204** | − 0.333** | 0.077 | 0.284** | − 0.241** | 0.133 |
| 25. | *Lepidocephalichthys guntea* | 0.322** | 0.584** | − 0.320** | 0.000 | −0.379** | 0.120 | − 0.323** | 0.256 |
| 26. | *Acanthocobitis botia* | 0.405** | 0.694** | − 0.326** | 0.031 | −0.459** | 0.133 | − 0.319** | 0.156 |
| 27. | *Paraschistura montana* | −0.372** | − 0.460** | − 0.038 | − 0.190** | 0.172* | 0.324** | − 0.116 | − 0.098 |
| 28. | *Schistura rupecula* | − 0.447** | − 0.565** | −0.110 | − 0.263** | 0.172* | 0.376** | − 0.199** | 0.017 |

**Table 2.** Continued.

| Sl. No. | Fish species | D | W | AT | WT | WV | DO | $CO_2$ | pH |
|---|---|---|---|---|---|---|---|---|---|
| 29. | *Schistura savona* | 0.463** | 0.698** | −0.298** | 0.032 | −0.319** | 0.129 | −0.275** | 0.192 |
| 30. | *Amblyceps mangois* | 0.610** | 0.841** | 0.038 | 0.321** | −0.237** | −0.136 | 0.058** | −0.048 |
| 31. | *Glyptothorax pectinopterus* | −0.329** | −0.428** | −0.112 | −0.240** | −0.202** | 0.307** | −0.158* | −0.027 |
| 32. | *Glyptothorax saisii* | −0.368** | −0.462** | −0.170* | −0.327** | 0.179* | 0.306** | −0.217** | 0.119 |
| 33. | *Clarias batrachus* | 0.638** | 0.816** | 0.035 | 0.285** | −0.166* | −0.176* | 0.071 | 0.030 |
| 34. | *Clarias gariepinnus* | −0.017 | −0.145* | 0.189** | 0.163* | 0.258** | −0.208** | 0.165* | −0.176 |
| 35. | *Heteropneustes fossilis* | 0.631** | 0.710** | −0.029 | 0.127 | −0.117 | −0.129 | 0.021* | 0.106 |
| 36. | *Mystus bleekeri* | 0.625** | 0.720** | 0.087 | 0.281** | −0.054 | −0.193** | 0.162* | −0.017 |
| 37. | *Xenentodon cancila* | 0.627** | 0.844** | −0.027 | 0.323** | −0.214** | −0.128 | 0.025 | 0.028 |
| 38. | *Macrognathus pancalus* | 0.321** | 0.642** | −0.199** | 0.243** | −0.325** | 0.052 | −0.235** | 0.114 |
| 39. | *Mastacembelus armatus* | 0.654** | 0.712** | −0.100 | 0.123 | −0.132 | −0.083 | −0.043 | 0.148 |
| 40. | *Badis badis* | 0.507** | 0.771** | −0.195** | 0.170* | −0.342** | 0.022 | −0.218** | 0.097 |
| 41. | *Trichogaster fasciata* | 0.495** | 0.596** | −0.043 | 0.070 | −0.130 | −0.080 | −0.006 | 0.129 |
| 42. | *Channa punctata* | 0.700** | 0.872** | 0.042 | 0.349** | −0.167* | 0.165* | 0.073 | −0.026 |
| 43. | *Channa gachua* | 0.697** | 0.728** | 0.081 | 0.225** | −0.048 | −0.369** | 0.213** | 0.163 |

**Table 2.** Continued.

| Sl. No. | Fish species | Hd | Alk | Turb | BOD | N | P | TDS |
|---|---|---|---|---|---|---|---|---|
| 1. | *Puntius chola* | −0.433** | −0.299** | −0.146* | −0.192** | 0.156* | 0.017 | 0.284** |
| 2. | *Pethia conchonius* | 0.398** | −0.256** | −0.171* | −0.173* | 0.295** | −0.047 | 0.379** |
| 3. | *Puntius sarana* | −0.442** | −0.315** | −0.110 | −0.219** | 0.162* | 0.042 | 0.311** |
| 4. | *Puntius sophore* | −0.427** | −0.293** | −0.134 | −0.187** | 0.169* | 0.024 | 0.298** |
| 5. | *Pethia ticto* | −0.392** | −0.256** | −0.172* | −0.183* | 0.293** | −0.053 | 0.379** |
| 6. | *Chagunius chagunio* | −0.416** | −0.325** | 0.155** | −0.234** | 0.120 | 0.088 | 0.440** |
| 7. | *Shizothorax richardsonii* | 0.224** | 0.023 | −0.104 | −0.146* | −0.303** | 0.531** | −0.477** |
| 8. | *Labeo dyocheilus* | −0.247** | −0.315** | 0.404** | −0.396** | −0.131 | 0.114 | 0.234** |
| 9. | *Bangana dero* | 0.026 | 0.047 | −0.209** | 0.003 | −0.117 | 0.194** | −0.272** |
| 10. | *Aspidoparia jaya* | −0.158 | −0.147** | 0.043 | −0.092 | 0.095 | 0.072 | 0.148 |
| 11. | *Cabdio morar* | −0.438** | −0.399** | 0.233** | −0.279** | 0.023 | 0.018 | 0.351** |
| 12. | *Osparius barna* | −0.541** | −0.393** | 0.171* | −0.241** | 0.160* | −0.144* | 0.517** |
| 13. | *Barilius bendelisis* | −0.131 | −0.114 | −0.336** | −0.145* | −0.054 | 0.228** | −0.315** |
| 14. | *Barilius vagra* | −0.030 | 0.036 | −0.424** | 0.096 | 0.163* | 0.295** | −0.180* |
| 15. | *Barilius shacra* | −0.243** | −0.189** | −0.016 | −0.111 | 0.178* | 0.086 | 0.302** |
| 16. | *Danio rerio* | −0.433** | −0.299** | −0.146* | −0.192** | 0.156* | 0.017 | 0.284** |

**Table 2.** Continued.

| Sl. No. | Fish species | Hd | Alk | Turb | BOD | N | P | TDS |
|---|---|---|---|---|---|---|---|---|
| 17. | *Devario devario* | − 0.392** | − 0.256** | − 0.172* | −0.183** | 0.293** | − 0.053 | 0.379** |
| 18. | *Esomus danrica* | − 0.427** | − 0.293** | − 0.134 | −0.187** | 0.169* | 0.024 | 0.298** |
| 19. | *Rasbora daniconius* | − 0.392** | − 0.256** | − 0.172* | − 0.183* | 0.293** | − 0.053 | 0.379** |
| 20. | *Crossocheilus latius* | 0.146* | − 0.054 | − 0.161* | −0.279** | −0.211** | 0.609** | − 0.495** |
| 21. | *Garra gotyla* | 0.165* | 0.044 | − 0.277** | −0.114 | −0.094 | 0.554** | − 0.548** |
| 22. | *Tor putitora* | − 0.127 | − 0.126 | − 0.202** | −0.142* | −0.044 | 0.286** | − 0.163* |
| 23. | *Tor tor* | − 0.468** | − 0.380** | 0.011 | −0.273** | 0.069 | − 0.008 | 0.288** |
| 24. | *Tor chelynoides* | 0.340** | 0.198** | − 0.185* | − 0.040 | −0.048 | 0.461** | − 0.382** |
| 25. | *Lepidocephalichthys guntea* | − 0.260** | − 0.090 | − 0.288** | −0.185* | 0.375** | 0.059 | 0.188** |
| 26. | *Acanthocobitis botia* | − 0.447** | − 0.302 | − 0.269** | − 0.333** | 0.209** | 0.051 | 0.122 |
| 27. | *Paraschistura montana* | 0.345** | 0.142* | − 0.086 | 0.032 | 0.213** | 0.673** | − 0.409** |
| 28. | *Schistura rupecula* | 0.441** | 0.273** | − 0.149* | 0.150* | − 0.119 | 0.683** | − 0.434** |
| 29. | *Schistura savona* | − 0.421** | − 0.402** | − 0.246** | −0.462** | 0.071 | 0.216** | 0.059 |
| 30. | *Amblyceps mangois* | −0.490** | −0.382** | 0.073 | −0.254** | 0.114 | 0.021 | 0.353** |
| 31. | *Glyptothorax pectinopterus* | 0.271** | −0.013 | − 0.122 | − 0.184* | − 0.369** | 0.545** | − 0.472** |
| 32. | *Glyptothorax saisii* | 0.331** | 0.110 | − 0.158* | − 0.153* | −0.206** | 0.625** | − 0.478** |
| 33. | *Clarias batrachus* | − 0.419** | − 0.300** | 0.061 | 0.171* | 0.214** | − 0.003 | 0.452** |
| 34. | *Clarias gariepinnus* | 0.236** | 0.295** | 0.181* | 0.456** | 0.257** | − 0.256** | 0.393** |
| 35. | *Heteropneustes fossilis* | − 0.330** | −0.218** | 0.017 | −0.150* | 0.284** | 0.078 | 0.429** |
| 36. | *Mystus bleekeri* | − 0.370** | − 0.299** | 0.179* | − 0.199** | 0.086 | 0.064 | 0.403** |
| 37. | *Xenentodon cancila* | − 0.422** | −0.277** | 0.043 | − 0.162* | 0.205** | − 0.012 | 0.475** |
| 38. | *Macrognathus pancalus* | − 0.235** | − 0.085 | − 0.232** | −0.023 | 0.358** | − 0.032 | 0.366** |
| 39. | *Mastacembelus armatus* | − 0.340** | −0.273** | − 0.064 | −0.214** | 0.261** | 0.153* | 0.385** |
| 40. | *Badis badis* | 0.416** | −0.270** | − 0.209** | 0.281** | −0.036 | 0.362** | 0.816** |
| 41. | *Trichogaster fasciata* | − 0.253** | − 0.193** | − 0.056 | − 0.150* | 0.232** | 0.137 | 0.314** |
| 42. | *Channa punctata* | − 0.468** | − 0.347** | 0.087 | −0.198** | 0.136 | − 0.004 | 0.484** |
| 43. | *Channa gachua* | − 0.298** | −0.240** | 0.080 | −0.195** | 0.245** | − 0.081 | 0.565** |

cannot directly influence the dispersal of fish species, rather its values are controlled by a number of other water quality parameters viz., $CO_2$, turbidity, BOD. From Tables 1 and 2 and the observations elaborated on this basis have clearly established that to which parameter maximum number of species show correlation (whether +ve or –ve).

As many as 25 species in East and 37 species in West were correlated with width which very well substantiates the fact that stream flow plays an important role in characterizing the distribution of fish species. The 12 species in East and 14 species in West were found to be correlated with depth whereas 12 species in East and 35 species in West were found to be correlated with water velocity. The 21 species in East and 11 species in West had correlation with DO indicating the influence of DO on the abundance of fish species. A negative correlation between $CO_2$ and fish species which was observed in the present findings in as many as 2 species in East and 4 species in West. In present study, cyprinids like *Barilius bendelisis* and *Barilius vagra* had –ve correlation with turbidity indicating that these species preferred to live in clear water. As many as 25 species in East and 4 species in West were correlated with Nitrates in downstream marshy and swampy sections, indicating the influence of nutrients on the dispersal of fishes. Nitrates make their way into stream through surface runoff after heavy irrigation and rainfalls.

The 19 and 9 species were correlated with phosphate in the East and West, respectively, whereas, 5 and 11 species were correlated with alkalinity (Tables

1 and 2). Physiological and behavioral responses of species to temperature and flow conditions (water velocity) are strong factors responsible for structuring fish assemblages. This fact is very well corroborated by the results of the present findings where as many as 14 species in East and 9 species in West were correlated with water temperature whereas 8 and 6 species, respectively were correlated with air temperature in East and West (Tables 1 and 2). In East *Schizothorax richardsonii*, *Tor chelynoides* and *Paraschistura montana* species were correlated with the highest number of water quality parameters whereas species like *Cyprinus carpio*, *Puntius sophore*, *Puntius terio*, *Labeo pangusia*, *Cabdio morar*, *Osparius tileo*, *Raiamas bola*, *Crossocheilus latius*, *Garra gotyla, Lepidocephalichthys annandalei, Glyptothorax telchitta, Clarias batrachus, Mystus bleekeri* were correlated with least number of parameters (Table 1). In West *Labeo dyocheilus* was correlated with the highest number of water quality parameters whereas species like *Bangana dero* and *Tor putitora* were correlated with least number of parameters (Table 2).

The analysis given above clearly establishes that to as many number of parameters, a particular species shows correlation (whether +ve or –ve or both), it falls in the category of more sensitive ones, but this category characteristically differs on the basis of changed habitat conditions in East and West. In East, *Schizothorax richardsonii*, *Tor chelynoides* and *Paraschistura montana* are the typical high altitude hill-stream-dwellers where their correlation with 10 parameters indicates their specificity of habitats of East ($S_{1,}$ $S_2$, $S_3$, $S_4$), but for the West their correlation attributes speak of a different story. The same may be said about other species.

**DISCUSSION**

The results of Pearson Product Moment Coefficient of Correlation (PPMCC) (Tables 1 – 2) have categorically revealed 7 correlation modes for both East and West. Fish responds to changes in its environment whether it is human induced or natural (Han et al. 2007). Local environmental factors play a vital role in structuring stream fish assemblage (Pires et al. 1999) and have significant impacts on stream habitat as well as fish assemblage (Wang et al. 2001). The 35 species in East and 4 species in West were correlated with BOD out of which 31 species were negatively correlated with BOD in the East. Kumar et al. (1990) also reported a negative correlation of fish species with BOD.

A study of Sheldon (1968) shows that in flowing waters, the number of fish was strongly correlated with the water depth. Stream morphological parameters like flow, depth and width greatly influence the fish community assemblages and are critical in the maintenance of fish populations (Pires et al. 1999, Paul and Meyer 2001, Lima–Junior et al. 2006). Bhat (2004) showed stream depth is correlated with species richness in the stream of Western Ghat, India. Stream depth also affects on fish assemblage in streams facing regular wet and dry seasons (Mesquita et al. 2006) and provides good spawning, feeding habitats and protection from predation (Angermeier and Winston 1998, Jackson et al. 2001). DO is one of the important variable in explaining the distribution of species (Fraser 1997). Depletion of DO makes the habitat unsuitable for fish life. In streams and rivers, DO define the pattern of fish assemblage on temporal and spatial scale (Mathews and Berg 1997).

A negative correlation between $CO_2$ and fish species which was observed in the present findings in as many as 2 species in East and 4 species in West, as also observed by Sharma and Shrestha (2001). Turbidity affects water color and reduces light penetration, which ultimately change the composition of fish assemblage (Akin et al. 2005). According to Costa et al. (2007) turbidity can influence the distribution of fishes in stream. Higher concentration of nitrates increases the production of native fishes because nitrates increase the production of aquatic plants (Wolgast and Stout 1977, Rashleigh 2004).

Dissolved phosphorus and alkalinity are important in regulating assemblage, composition, but to a lesser extent (Marvin 1997).

The works Arceo – Carranza and Vega – Cendejas (2009), Jayaratne and Surasinghe (2010), Sumith et al. (2011), Daga et al. (2012) are worth quoting, as they also discussed the tolerance to habitat variations and resistant to changes in water quality. In East, *Schizothorax richardsonii, Tor chelynoides* and *Paraschistura montana* are the typical high altitude hill-stream-dwellers where their correlation with 10 parameters indicates their specificity of habitats of East ($S_1$, $S_2$, $S_3$, $S_4$), but for the West their correlation attributes speak of a different story. The same may be said about other species.

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