E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2020; 8(4): 333-337

www.fisheriesjournal.com
Received: 01-04-2020
Accepted: 03-05-2020

Correlation between Physico-chemical and ecological variables in a riverine system: A case study

Megha Khanduri, Dr. Amita Saxena, Dr. Hema Tewari and Dr. Raj Narayan Ram

Megha Khanduri
Department of Fisheries Resource Management, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Dr. Amita Saxena
Professor & Head, Department of Fisheries Resource Management, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Dr. Hema Tewari
Professor & Head, Department of Aquatic Environment Management, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Dr. Raj Narayan Ram
Professor, Department of Fisheries Resource Management, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Corresponding Author:
Megha Khanduri
Department of Fisheries Resource Management, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Abstract
A study was conducted at Bijnor district in the Upper Gangetic Plains of Uttar Pradesh from August 2019 to March 2020 to explore the inter-dependence of some selected water quality parameters and two ecological communities *viz.* Plankton and Ichthyofauna of the river Ganges at the site. Through the period of the study, the site had relatively scarce zooplankton and the fish-fauna consisted mainly of carnivorous catfishes and snakeheads, with very few species of herbivores and planktivores. A correlation analysis between the variables indicates a negative correlation between water temperature and zooplankton density as well as between water temperature and fish species diversity. The study thus brings to light a possible role of rising water temperatures in altering community structures and food webs in freshwater lotic habitats.

Keywords: Ecological interactions, Ganges, ichthyo-diversity, plankton, water temperature

1. Introduction
The Ganges, India's largest and the world's fifth-longest river [1], harbours various biological communities and species, and these are affected by various abiotic and biotic factors within the river. The Ganga Basin sustains over 450 million people, who also depend on its fisheries among other commodities and services [2]. Thus everything that influences life in the waters of the river also sustains life on the land that lies on its banks.
The fish diversity in an aquatic habitat is influenced by various factors, both abiotic and biotic. Ecological as well as evolutionary factors exert their influence on the biodiversity of aquatic systems. These include evolutionary speed, geographic area, inter-specific interactions, ambient energy, productivity and disturbance. Although, in streams with highly variable flow and temperature regimes, the intermediate disturbance hypothesis may not hold true [3]. The fish diversity of the Ganges has been known to change under the influence of indiscriminate fishing, pollution, water abstraction, siltation and the introduction of non-native species [1]. The hydrobiological characteristics of the Ganga itself have changed through the years. For example, a comparison of previous studies involving the water temperature of the river at Haridwar [4, 5] suggests an increase in the temperature between these studies. Since the state of the river is susceptible to change, it stands to reason that the same would go for its biological communities. A shift in the ichthyo-diversity of the Ganges has already been reported, with a spread of warm-water species into the colder stretches [6]. A trophic shift towards carnivorous species has also been observed in the ichthyofauna community of the river as larger bodied carps have been replaced by smaller prey species [7].
In this study, an attempt has been made to gain an understanding of the interactions between various abiotic and biotic elements within the river over a short span of time encompassing a few months, in order to predict how long-term changes in its environment are likely to affect its ecology.

2. Materials and Methods
2.1. Sampling site and schedule
The samples were collected monthly during the first week of every month from August 2019 to March 2020. The water samples were collected from the river Ganges at Madhya Ganga Barrage, Bijnor district, Uttar Pradesh, located 29°22'24.45" N, 78°02'17.44" E at 220 m above mean sea level [8].

The fish were identified at the landing and auction centre in Bijnor.

2.2. Sample Collection and Analysis

The samples were collected monthly between 8:00 and 10:00 a.m. The water temperature and TDS were recorded on site using a hand-held digital thermometer and TDS-meter. The water samples were collected in plastic bottles without air bubbles, and in 250-ml stoppered glass bottles for fixing Oxygen at the site. Plankton collection was done by filtering 50 l of water through a plankton net. The collected sample was then preserved in 3-4% formalin, and identified with the help of reference literature[9].The water quality parameters were analysed following standard procedures as described by APHA (2005) [10].
Fishes were procured from local commercial fishermen at the landing and auction site, and identified with the help of keys from Talwar and Jhingaran (1991) [11].

2.3. Biological Indices and Statistical Analysis

The Shannon's Index was calculated using the vegan package of R 4.0.0. Margalef's Index [12] was calculated using the formula:

$$D_{Mg} = (S-1)/\ln(n)$$

Where S = total number of species encountered, and
n = total number of individuals encountered
IBM SPSS Statistics 21 was used for the statistical analysis of the data. GGCorrplot package of R 4.0.0 was used to create the correlation matrix.

3. Results

A total of twelve variables were studied, which included five physico-chemical parameters *viz.* Water Temperature, Dissolved Oxygen, Total Dissolved Solids, Total Alkalinity and Biochemical Oxygen Demand. Two ecological communities were selected to study the influence of changes in the aforementioned physico-chemical parameters on them. The first community was the plankton community, for which the parameters of phytoplankton density and zooplankton density were recorded. For the fish-fauna, the parameters of Margalef's Index and Shannon index were recorded. The percentage of herbivorous/planktivorous, omnivorous and carnivorous species observed every month was also recorded. The mean values of the parameters and their standard deviation are given in Table 1.

Table 1: Values for the various parameters studied

	Minimum	Maximum	Mean	Std. Deviation
Temperature (°C)	15.60	23.30	18.5125	2.84074
Dissolved Oxygen (ppm)	8.00	11.00	9.6750	1.25556
Total Dissolved Solids (ppm)	100.00	120.00	109.2500	8.92428
Total Alkalinity (ppm)	64.00	130.00	86.2500	21.65806
Biochemical Oxygen Demand (ppm)	3.00	4.60	3.7250	.65846
Phytoplankton Density (no. x 10^3 l^{-1})	30.00	180.00	99.3750	57.78269
Zooplankton Density (no. ml^{-1})	0.00	3.00	.5000	1.06904
Fish Margalef Index	2.17	3.02	2.5525	.26429
Fish Shannon Index	1.67	2.37	2.1313	.23357
Carnivorous Fish Percentage (%)	52.38	66.67	60.1738	5.66138
Herbivorous Fish Percentage (%)	21.05	25.00	23.1313	1.43561
Omnivorous Fish Percentage (%)	11.11	23.81	16.6950	5.54687

The average water temperature over the period of the study was observed to be 18.51 ± 2.84 °C. The Dissolved Oxygen content remained fairly high, averaging 9.68 ± 1.26 ppm. The Total Dissolved Solids had an average concentration of 109.25 ± 8.92 ppm, and the Total Alkalinity had an average value of 86.25 ± 21.66 ppm. The average Biochemical Oxygen Demand was 3.73 ± 0.66 ppm.
Phytoplankton was represented by Chlorophyceae, Euglenophyceae, Cyanophyceae, Dinophyceae and Bacillariophyceae. Chlorophyceae was represented by *Spirogyra* and *Closterium*; Euglenophyceae by *Euglena*, Cyanophyceae by *Microcystis*; Dinophyceae by *Ceratium* and *Gymnodinium*, and Bacillariophyceae was represented by *Navicula*, *Nitzschia* and *Tabellaria*. The average phytoplankton density over the period of the study was 99.38 ± 57.78 x 10^3 l^{-1}
Zooplankton was scarce, and only recorded in two months. These were represented by *Amoeba* and *Cyclops*. The average zooplankton density was 0.50 ± 1.07 ml^{-1}.
The fishes procured from the landing and auction site belonged to 14 families *viz.* Notopteridae (*Notopterus notopterus* and *Chitala chitala*), Cyprinidae (*Labeo rohita*, L. *gonius, L. dyocheilus, L. calbasu, Cirrhinus mrigala, C. reba, Cyprinus carpio*, *Puntius sophore*, *Tor putitora*, *Rasbora daniconius* and *Salmostoma phulo*), Bagridae (*Sperata seenghala*, *Mystus tengara* and *Rita rita*), Sisoridae (*Bagarius bagarius*), Siluridae (*Wallago attu*, *Ompok pabda*), Heteropneustidae (*Heteropneustes fossilis*), Channidae (*Channa striatus*, *C. punctatus* and *C. marulius*), Gobiidae (*Glossogobius giuris*), Osphronemidae (*Trichogaster fasciata*), Ambassidae (*Chanda nama* and *Ambassis ranga*), Nandidae (*Nandus nandus*), Anabantidae (*Anabas testudineus*), Mastacembelidae (*Mastacembelus armatus*) and Belonidae (*Xenentodon cancila*). Of these, 60.17 ± 5.66% species had carnivorous feeding habits, 23.13 ± 1.44% had herbivorous or planktivorous feeding habits and 16.70 ± 5.55% of the total species recorded were of omnivorous feeding habits. The values for Margalef Index and Shannon Index for fish were 2.55 ± 0.26 and 2.13 ± 0.23 respectively.
Furthermore, an analysis of correlation between these variables was also done, and is shown in Table 2 and Fig. 1. Significant correlation was observed between various physico-chemical parameters, plankton density, as well as fish-fauna (Table 2). The most important of these have been discussed further.

Table 2: Correlations between the parameters of the study

		Water Temperature	Dissolved Oxygen	Total Dissolved Solids	Total Alkalinity	Biochemical Oxygen Demand	Phytoplankton Density	Zooplankton Density	Fish Margalef Index	Fish Shannon Index	Carnivorous Fish Percentage	Herbivorous Fish Percentage	Omnivorous Fish Percentage
Water Temperature	Pearson Correlation	1	.887**	.664	-.712*	-.802*	.738*	-.106	-.534	-.039	.833*	-.154	-.810*
	Sig. (2-tailed)		.003	.073	.047	.017	.037	.803	.173	.927	.010	.716	.015
Dissolved Oxygen	Pearson Correlation	.887**	1	.528	-.785*	-.963**	.798*	.181	-.515	-.287	.903**	-.326	-.838**
	Sig. (2-tailed)	.003		.178	.021	.000	.018	.668	.192	.491	.002	.431	.009
Total Dissolved Solids	Pearson Correlation	.664	.528	1	-.472	-.575	.656	.374	-.368	-.145	.390	-.380	-.300
	Sig. (2-tailed)	.073	.178		.238	.136	.078	.361	.370	.732	.339	.354	.470
Total Alkalinity	Pearson Correlation	-.712*	-.785*	-.472	1	.785*	-.738*	-.191	.435	.112	-.687	.654	.531
	Sig. (2-tailed)	.047	.021	.238		.021	.036	.650	.281	.791	.060	.078	.175
Biochemical Oxygen Demand	Pearson Correlation	-.802*	-.963**	-.575	.785*	1	-.846**	-.386	.547	.423	-.823*	.403	.735*
	Sig. (2-tailed)	.017	.000	.136	.021		.008	.345	.160	.296	.012	.322	.038
Phytoplankton Density	Pearson Correlation	.738*	.798*	.656	-.738*	-.846**	1	.468	-.195	.016	.556	-.579	-.418
	Sig. (2-tailed)	.037	.018	.078	.036	.008		.242	.643	.969	.152	.132	.303
Zooplankton Density	Pearson Correlation	-.106	.181	.374	-.191	-.386	.468	1	.015	-.363	-.008	-.666	.180
	Sig. (2-tailed)	.803	.668	.361	.650	.345	.242		.972	.376	.986	.071	.669
Fish Margalef Index	Pearson Correlation	-.534	-.515	-.368	.435	.547	-.195	.015	1	.602	-.712*	-.041	.737*
	Sig. (2-tailed)	.173	.192	.370	.281	.160	.643	.972		.114	.048	.923	.037
Fish Shannon Index	Pearson Correlation	-.039	-.287	-.145	.112	.423	.016	-.363	.602	1	-.288	-.095	.319
	Sig. (2-tailed)	.927	.491	.732	.791	.296	.969	.376	.114		.488	.823	.441
Carnivorous Fish Percentage	Pearson Correlation	.833*	.903**	.390	-.687	-.823*	.556	-.008	-.712*	-.288	1	-.206	-.967**
	Sig. (2-tailed)	.010	.002	.339	.060	.012	.152	.986	.048	.488		.625	.000
Herbivorous Fish Percentage	Pearson Correlation	-.154	-.326	-.380	.654	.403	-.579	-.666	-.041	-.095	-.206	1	-.049
	Sig. (2-tailed)	.716	.431	.354	.078	.322	.132	.071	.923	.823	.625		.909
Omnivorous Fish Percentage	Pearson Correlation	-.810*	-.838**	-.300	.531	.735*	-.418	.180	.737*	.319	-.967**	-.049	1
	Sig. (2-tailed)	.015	.009	.470	.175	.038	.303	.669	.037	.441	.000	.909	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

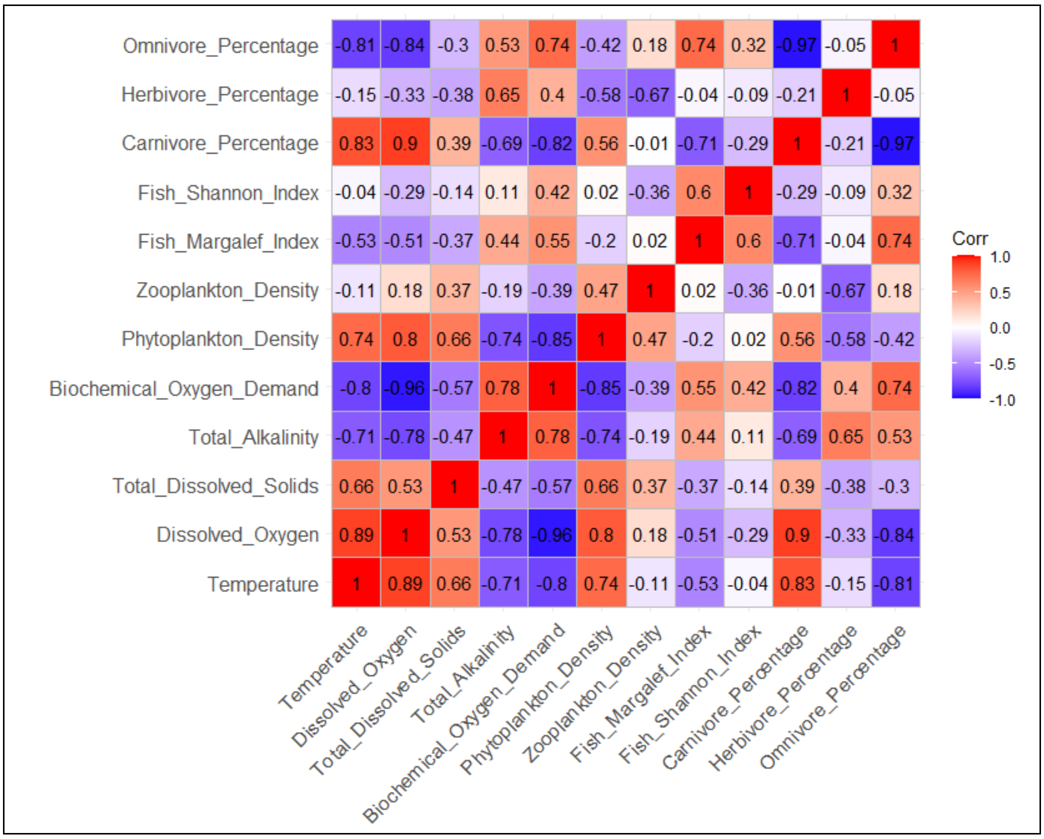

Fig 1: Correlation matrix for the parameters of the study

4. Discussion

The study explores correlations between some parameters of water quality and two ecological communities, *viz.* Plankton and Ichthyofauna of a riverine ecosystem in a channel obstructed by a barrage.

The phytoplankton density is positively correlated with the water temperature, total alkalinity and total dissolved solids. Significant positive correlation between temperature and phytoplankton density, phytoplankton density and dissolved oxygen, as well as between dissolved oxygen and temperature suggests that photosynthesis is a major source of dissolved oxygen in the river. This is to be expected, as photosynthesis and community respiration are the major processes governing the dynamics of dissolved oxygen in a fluviatile system [13]. The zooplankton density, however, has a negative correlation to the water temperature. Various studies [14] have shown a displacement of oceanic zooplanktonic species to higher latitudes in response to rising Sea Surface Temperature. It is possible that a similar phenomenon could be responsible for the scarcity of zooplankton.

The plankton density showed variations through the period of the study, and zooplankton remained few or absent in most cases. It is, therefore, no surprise that the number of planktivorous and herbivorous fish species remains low throughout the period of the study. With regards to ichthyo diversity, more than 60% of all recorded species were found to be carnivorous. This observation is similar to that made by Das *et al.* (2013) [7], who observed that the replacement of larger carps by smaller prey species is causing a shift towards carnivorous species in the Ganges.

A major factor affecting the fish species diversity was observed to be water temperature, which has a negative correlation with the fish diversity indices. This should be taken as an indication to just how serious a threat climate change poses to riverine fish diversity. Upon further inspection, the correlation analysis between water temperature and the number of species of different feeding habitats reveals that water temperature has a negative correlation with the percentage of herbivorous and omnivorous(significant) species, but has a significant positive correlation with carnivorous species. Also considering the negative correlation between water temperature and zooplankton density, it stands to reason that the meagre representation of planktivorous species could be a result of match-mismatch phenomena involving zooplankton abundance and zooplanktivorous fish larvae, thus resulting in a failure in recruitment of such species. A similar climate change-driven decoupling of predator-prey interaction has been observed in Lake Washington [15]. Rising average temperatures have also been reported to affect other communities, such as stream macroinvertebrates. Studies have shown that changing temperatures affected the community differently in different habitats, and different species showed different responses to the change[16]. An increase of 1.88℃ in a German headwater stream accompanied by changes in the water discharge over a period of 42 years was observed to affect the insects of the stream.These stressors resulted in a decrease in insect abundance but increase in species richness and diversity and evenness [17].

5. Conclusion

The study suggests an influence of water temperature on the phytoplankton and zooplankton density, thus indirectly influencing community photosynthesis and respiration and consequently the oxygen dynamics in the riverine ecosystem. Both phytoplankton and zooplankton, being a major food source for various fish species, affect the fish assemblage in the river as well. The study indicates an influence of the zooplankton community on the fish assemblage, by affecting the populations of zooplanktivorous species and consequently the diversity and abundance of various other herbivorous, carnivorous as well as omnivorous fishes.

This role of temperature in indirectly affecting the fish diversity of a riverine ecosystem through its influence on the food web has been inferred from data collected over eight months. The fact that the fish assemblage in the Ganges responds to even short-term temperature changes associated with the seasons, suggests that a long-term change in the temperature regime of the river driven by climate change can have adverse, permanent repercussions for the river's ecosystem. Thus there is a need to study such climate-related phenomena with some historical context in order to understand how climate change has affected existing ecosystems and to predict its influence on vulnerable ecosystems, so that these effects can be mitigated.

6. References

1. Sarkar UK, Pathak AK, Sinha RK, Sivakumar K, Pandian AK, Pandey A *et al.* Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives. Reviews in Fish Biology and Fisheries. 2011; 22(1):251-272.
2. Kumar D. River Ganges – Historical, cultural and socioeconomic attributes. Aquatic Ecosystem Health & Management. 2017; 20(1, 2):8-20.
3. Geist J. Integrative freshwater ecology and biodiversity conservation. Ecological Indicators. 2011; 11(6):1507-1516.
4. Swaroop Bhargava D. Use of water quality index for river classification and zoning of Ganga river. Environmental Pollution Series B, Chemical and Physical. 1983; 6(1):51-67.
5. Bhutiani R, Khanna DR, Kulkarni DB, Ruhela M. Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices. Applied Water Science. 2016; 6:107-113
6. Das MK, Naskar M, Mondal ML, Srivastava PK, Dey S, Rej A. Influence of ecological factors on the patterns of fish species richness in tropical Indian rivers. Acta Ichthyologia et Piscatoria2012; 42(1):47-58.
7. Das MK, Sharma AP, Vass KK, Tyagi RK, Suresh VR, Naskar M *et al*. Fish diversity, community structure and ecological integrity of the tropical River Ganges, India, Aquatic Ecosystem Health & Management. 2013; 16(4):395-407
8. Google Earth Pro. Map of Ganga Barrage, Bijnor, Uttar Pradesh, India. 2019
9. Edmondson WT, Henry BW. Freshwater Biology. 2. John Wiley & Sons Inc, New York, 1992
10. APHA Standard methods for the examination of water and wastewater. American Public Health Association, Washington, DC, 2005
11. Talwar PK, Jhingran AG. Inland Fishes of India and Adjacent Countries. Oxford-IBH Publishing Co. Pvt. Ltd., New Delhi, 1991
12. Margalef R. Information theory in ecology. General Systems. 1959; 3:36-71
13. Wang H, Hondzo M, Xu C, Poole V, Spacie A. Dissolved oxygen dynamics of streams draining an urbanized and an agricultural catchment. Ecological Modelling. 2003; 160(1, 2):145-161.
14. Richardson AJ. In hot water: zooplankton and climate change. ICES Journal of Marine Science. 2008; 65(3):279-295. doi:10.1093/icesjms/fsn028
15. Winder M, Schindler DE. Climate Change Uncouples Trophic Interactions in an Aquatic Ecosystem. Ecology. 2004; 85(8):2100-2106.
16. Jourdan J, O'Hara RB, Bottarin R, Huttunen KL, Kuemmerlen M, Monteith D *et al*. Effects of changing climate on European stream invertebrate communities: A long-term data analysis. Science of The Total Environment. 2018; 621:588-599.
17. Baranov V, Jourdan J, Pilotto F, Wagner R, Haase P. Complex and nonlinear climate-driven changes in freshwater insect communities over 42 years. Conservation Biology. 2020; 0(0):1-11.