Stress Evaluation on Ecological Integrity of Selected Lotic Water Bodies

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Abstract

The water quality of the freshwater streams of Pakistan has been degraded with time. The present study aims to explore the water quality and ichthyofauna diversity from the lotic water bodies of the Sialkot. Ten sampling sites were evaluated for pollution levels and ichthyofauna of the Sialkot region. Physicochemical parameters such as pH, temperature, biological oxygen demand (BOD), and total dissolved substance (TDS) were found to be disturbed. In addition, correlation analysis of water quality parameters was studied. The strongest positive correlation (1.0) was observed between alkalinity and bicarbonate. In contrast, a robust positive correlation (0.99) was observed between EC and TDS, whereas pH shows a moderate, weak negative (-0.30) correlation with EC, TDS, Alkalinity, and Bicarbonate, respectively. Moreover, a total of 22 fish species belonging to 10 families were studied and identified. The composition of the fish assemblage mainly belongs to the family Cyprinidae (41%), while the rests of the families contribute 59% to fish assemblage. Our results indicate that the amount of pollutants and overfishing by using pesticides and illegal mesh size is the main reason for reducing the fish population. During the current study, we found surface water quality of streams is being degraded day by day due to the accumulation of pollutants from industrial and domestic sewage waste. It is recommended that severe measures are needed to stop such water contamination, and regular monitoring should be undertaken to monitor the water quality in the study area.

Introduction

Developing countries such as Pakistan face surface water contamination (Saleem et al. 2014; Jabeen et al. 2015) which can cause severe pressures on the aquatic ecosystem. Fish are significant as well as sensitive members of food chains in the marine habitat. Mostly, the fish species move to less polluted areas due to dreadful organisms found in the contaminated water (Azmat et al. 2016; Malik et al. 2009). Poisonous effects are increased when different chemical reactions in the body of organisms are unable to detoxify the metals.

In developing countries, degrading water quality poses toxic effects on the aquatic ecosystem. This one is a major cause of human health (Mubedi et al.2013; Pritchard et al. 2008; Suthar et al. 2009). Rapid urbanization, industrialization, and agricultural activities are the main causes for the contamination of water through heavy metals with the assimilation into the food chains (Iqbal et al. 2016; Alyahya et al. 2011). A substantial quantity of toxic metals can lead to many lethal diseases such as cancer and psychological and cardiovascular disorders (Ali et al. 2013; Singh et al. 2015)). Earlier studies have shown that streams and rivers are being polluted due to the dumping of untreated municipal and industrial wastewater and agricultural runoff in the river ecosystem (Kaile et al. 2016; Su et al. 2016).

Materials And Methods

Study area

The current study mainly focuses on Nullah Aik, Nullah Palkhu (Tributaries of the River Chenab), and associated seasonal drains (Fig: 1). These freshwater streams traverse through the city of Sialkot from east to west and converge downstream near Wazirabad city before falling into Chenab River. These streams collect municipal sewage and industrial runoffs from different regions of Sialkot City, which damage the water quality and upset the ecological integrity. As a result, the contamination of water and overfishing creates instabilities to natural fish assemblages (Akbar et al. 2010; mirza et al. 2011).

Water sampling

Water samples were taken about 25 cm below the surface of the water. Twenty water samples were collected from 10 selected sites to obtain composite samples and stored in pre-cleaned HNO_3 plastic bottles. Water samples were tightly sealed to avoid leakage and placed in iceboxes during transportation. All models were preserved and transported to a water quality laboratory, Pakistan council of research in water resources (PCRWR), Gujranwala for water analysis according to prescribed standard methods (APHA, 1998).

Physicochemical parameters

Eight Physicochemical parameters of water samples such as pH, temperature, biological oxygen demand (BOD), electrical conductivity (EC), Bicarbonate (HCO_3), Alkalinity, Total dissolved solids (TDS) and Nitrate were analyzed. Furthermore, correlation statistics were used to determine the relationship among different physicochemical parameters of water.

Fish Sampling

The fish specimens were collected using verities of nets i.e. gill and cast nets(Kubečka et al. 2012; Jega et al. 2015). Fish sampling was started early in the morning, usually commencing from 5:00 am to 12:00 pm. The habitat descriptions and fish catch data for each site were used to determine the fish distribution pattern. The selection of sites was based on different habitat characteristics such as emergent macrophytes, riparian vegetation, and open water availability (mirza et al. 2003). After capturing, the fish specimens were immediately released into the stream to minimize their mortality—data recorded of fish abundance in detail given in statistical analysis.

Statistical Analysis

The fish data were analyzed by various methods such as diversity indices, the Shannon (H), and Simpson (D) index by using PCOrd 4 software (Iqbal et al. 2017). Shannon index (H) mostly assumes all species represented a community which is randomly sampled and determine the richness of species similarly Simpson index (D) is used to evaluate dominance and gives additional weightage to dominant species present in any ecosystem (Saint-Paul et al. 2000). Moreover, Cluster Analysis was applied to fish data for the classification of study sites by Ward's method with Euclidean distance using Statistica 10.2 software. In order to study fish assemblages and habitat similarity ordination techniques such canonical correspondence analysis (CCA) was used for determining correlation between environment and fish species.

Results

Physiochemical variables of water

The mean, standard deviation, and range values of 8 physicochemical water samples are given in [Table 1]. At the same time, the percentages in each site of these water quality parameters are shown in (Fig. 2). In the case of physicochemical parameters during the study period, the level of biological oxygen demand (BOD) was found to be in the range of 38.9–57.2 mg/L with the minimum level (38.9 mg/L^{-1}) from site 2, while the maximum was from site 7. The concentration of total dissolve substances (TDS) was in the range between 110.0-734.0 mg/L with the mean value of 292.40mg/L. Total dissolve substances are considered the main factor for the growth of plants and the taste of water (Valipour et al. 2014; WHO, 2004). Moreover, the total dissolve substances level depends on numerous factors such as rainfall, amount of surface runoff, and the geological character of the watershed. Nitrate in the stream samples was in a range between 22.0–42.0 mg/L with a maximum value from site 10 and the minimum from site 1. Bicarbonate was found to be ranged from 140–480 with a mean value of 268.0 mg/L. Maximum bicarbonate 480 mg/L was recorded from site 2, whereas the minimum was recorded from sites 4, 7, 8 and 10. Whereas the temperature and pH was in range between 28–29 and 6.3–7.1. While alkalinity and electrical conductivity (EC) was found to be in ranged between 2.80–9.60 (mmol/L) and 207.0-1386.0 (µsec/cm) respectively.

Table 1
Descriptive statistics of water quality data from district Sialkot

Parameters	Mean ± SD	Max-Mini
pH	6.78 ± 0.27	6.30–7.10
Temperature	29.07 ± 0.26	28.-29.
EC	554.50 ± 425.68	207.0-1386.0
Alkalinity	5.36 ± 2.55	2.80–9.60
Bicarbonate	268.0 ± 127.61	140.0-480.0
Nitrate	31.97 ± 6.45	22.0–42.0
BOD	47.40 ± 6.86	38.9–57.2
TDS	292.40 ± 226.27	110.0-734.0

Correlation among water quality parameters

The correlation analysis of eight water quality parameters was studied [Table 2]. The results showed a moderate, weak negative (-0.30) correlation of pH with electrical conductivity (EC), total dissolve substances (TDS), Alkalinity, and Bicarbonate, respectively.

Table 2
Correlation data of water quality parameters of District Sialkot

	pH	Temperature	EC	Alkalinity	Bicarbonate	Nitrate	BOD	TDS
pH	1							
Temperature	0.36	1						
EC	-0.30	0.10	1					
Alkalinity	-0.38	0.03	**0.89**	1				
Bicarbonate	-0.38	0.03	**0.89**	**1**	1			
Nitrate	-0.01	0.06	**0.68**	0.39	0.39	1		
BOD	0.02	0.11	-0.04	0.05	0.05	0.27	1	
TDS	-0.30	0.10	**0.99**	**0.89**	**0.89**	**0.68**	-0.05	1

The strongest positive correlation was observed between alkalinity and bicarbonate (1.0), while a very strong positive correlation (0.99) was observed between electrical conductivity (EC) and total dissolve substances (TDS). Similarly, a positive correlation (0.89) of total dissolve substances (TDS) was observed with alkalinity and bicarbonate, whereas in the case of nitrate, total dissolve substances (TDS) shows a moderate positive correlation (0.68).

Fish fauna

A total of 22 fish species belonging to 10 families were collected during the current study. Fish assemblage sampled from 10 selected sites is shown in [Table 3]. The fish assemblage composition mainly belongs to the family Cyprinidae (41%), while the rest of the families contribute 51%. Based on the abundance, fish species were categorized into three groups: more than 3% (abundant), 0.51-2% (less common), and less than 0.5% were categorized as rare species. Out of 22 fish species, 4 were classified as abundant, 12 were less common, and 6 were rare [Table 4]. *Puntius sophomore and Puntius ticto* exhibited the highest relative abundance of 53.38 and 19.75%, respectively *Rita rita, Catla catla, Garra gotyla, Labeo calabash, Osteobrama cotio and Xenentodon cancila* were listed as rare with the lowest relative abundance. The highest relative abundance (26.86%) was reported from Roras outfall drain (Sambrial), while Kotli Marlanwali site showed the lowest relative aundance (1.95%). Moreover, cluster analysis (CA) was applied to fish data to recognize the resemblances among study sites (Fig. 3)Cluster analysis (CA) classified the sites into two renowned groups (A and B) based on the abundance of fish species. Group A was represented by S7 (Roras outfall drain), S8 (Begowala link drain), and S10 (Nullah Palkhu, Airport area) whereas group B was represented by S1 (Umranwali), S2 (Uoora), S3 (Pul Aik, Sialkot city), S4 (Kotli Marlanwali), S5(Nullah Palkhu, Jaurian) and S9 (Sambrial link drain). Overall, group A was represented with higher fish catch and maximum fish richness. During the study, it was found that S7, S8, and S10 were very diverse than other sites. This might be due to better water quality with minimum pollutants as compared to the rest of the sampling sites. It is well recognized that the massive concentration of metals and other contaminations in streams might have poisonous effects on the fish fauna of the Sialkot region. To lessen interaction to pollutants, aquatic organisms move from vastly polluted to a smaller amount polluted zones of the stream. The highest fish richness (12) was reported from Roras outfall drain, while the lowest (3) was from the Sambrial link drain and Uoora site. In the same way, diversity indices (Shannon’s and Simpson’s) were found to be maximum from Kotli Marlanwali (S4).

Table 3

Total number of Fish specimens, Species richness, Evenness, Shannon$s\mathrm{and}Simpson$s diversity index Calculated from 10 sampling sites from district Sialkot

Site	Total individual	Maximum	Species Richness	Evenness	Shannon`s diversity index	Simpson`s diversity index
Umranwali	22	14	6	0.647	1.160	0.5537
Uoora	56	53	3	0.221	0.243	0.1027
Pul Aik, Sialkot city	18	7	6	0.884	1.584	0.7593
Kotli Marlanwali	11	3	6	0.960	1.720	0.8099
Nullah Palkhu (Jaurian)	51	31	8	0.626	1.301	0.5921
Kotli Khokhran	26	17	7	0.640	1.246	0.5503
Roras out fall drain	151	79	12	0.652	1.620	0.6842
Begowala link drain	98	67	8	0.499	1.039	0.4919
Sambrial link drain	43	21	3	0.717	0.787	0.5224
Nullah Palkhu (Airport area)	86	43	11	0.697	1.671	0.7061

Table 4
Fish distribution and abundance data collected from District Sialkot

S#	Family	Species	SITES										Relative Abundance	Fish status	Habits
			S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	(%)		
1	*Bagridae*	*Mystus bleekri*	0	0	0	2	0	0	6	0	0	0	1.42	Less common	Carnivore
2		*Mystus cavasius*	0	1	3	0	0	1	23	0	0	7	6.22	Abundant	Carnivore
3		*Rita rita*	0	0	0	0	1	2	0	0	0	0	0.53	Rare	Carnivore
4	*Chandidae*	*Parambasis ranga*	0	0	0	0	1	0	4	1	0	0	1.06	Less common	Omnivore
5		*Channa marulia*	0	0	0	0	0	2	0	1	0	3	1.06	Less common	Carnivore
6		*Channa punctate*	1	0	0	0	1	0	13	3	0	11	5.16	Abundant	Carnivore
7	*Osphronimidae*	*Polyacanthus fasciata*	1	0	0	2	0	0	1	0	0	0	0.71	Less common	carnivore
8	*Cichlidae*	*Oreochromis niloticus*	0	0	0	0	4	2	5	0	0	0	1.95	Less common	Omnivore
9	*Cyprinidae*	*Catla catla*	0	0	0	0	0	1	0	0	0	2	0.53	Rare	Herbivore
10		*Cirrhinus mrigala*	0	0	0	1	0	0	3	0	1	1	1.06	Less common	Herbivore
11		*Cyprinus carpio*	0	0	0	0	4	0	0	3	0	1	1.42	Less common	Herbivore
12		*Garra gotyla*	0	0	1	0	0	0	0	0	0	0	0.17	Rare	Herbivore
13		*Labeo calbasu*	0	0	0	1	0	0	0	0	0	0	0.17	Rare	Herbivore
14		*Labeo rohita*	1	0	1	0	0	1	0	3	0	0	1.06	Less common	Herbivore
15		*Osteobrama cotio*	0	0	0	0	1	0	0	0	0	3	0.71	Rare	Omnivore
16		*Puntius sophore*	14	53	7	0	31	17	79	67	21	11	53.38	Abundant	Herbivore
17		*Puntius ticto*	4	0	3	0	8	0	13	19	21	43	19.75	Abundant	Herbivore
18	*Belonidae*	*Xenentodon cancila*	0	2	0	0	0	0	0	0	0	0	0.35	rare	Carnivore
19	*Heteropneustidae*	*Heteropneustes fossilis*	0	0	3	0	0	0	1	0	0	3	1.24	Less common	Carnivore
20	*Mastacembelidae*	*Macrognathus pancalus*	0	0	0	3	0	0	1	0	0	1	0.88	Less common	Carnivore
21	*Notopteridae*	*Notopterus notopterus*	0	0	0	0	0	0	2	1	0	0	0.53	Less common	Carnivore
22	*Sisoridae*	*Gagata cenia*	1	0	0	2	0	0	0	0	0	0	0.53	Less common	Carnivore

Discussion

Spatiotemporal variation in water quality

The temperature of water increases the sensitivity of several organisms towards toxic waste. Industrial process waste discharge and air temperature are two major factors that influence water temperature. Higher temperatures might raise the rate of metabolism in living organisms within their thermal tolerance range; beyond this range cause a decline of metabolic processes and decrease performance (Kroeker et al. 2013). Moreover, the rate of photosynthesis is also controlled by temperature (Brown et al. 2004) and physiological processes like the release of stimulus for breeding in fish species, both under artificial and natural processes(Muralidharan et al. 2014). One of the extreme anthropogenic stresses is the release of hot water from power stations and industries that cause an abrupt change in water temperature (Riđanović et al. 2010).

Measurement of pH is very significant as an indicator of water quality. Aquatic life is sensitive to ecological pH variations, and the suitability of drinking water is also pH-dependent (Al Shujairi et al. 2013). In the present study conducted in Sialkot district regions, it was found the water pH was slightly alkaline to neutral during different seasons; thus, during the current study, slightly higher pH values were observed in freshwater streams. Rainwater during the wet season dissolve many gases present in the air, which later became a part of the freshwater streams through the atmospheric wet deposition. Water pH reduced as these gases were acidic. It is also affected by bicarbonate, carbonate, and carbon dioxide equilibrium. Fluctuations in the pH value of the water might be attributed to the anthropogenic stress in catchments like domestic sewage disposal, improper irrigation practices, weathering of the parent rock, and industrial discharge (Kumar et al. 2015). Decomposition process going on in aquatic ecosystem which on biological oxidation releases carbon dioxide is another significant factor (Verma et al. 2012). Moreover, decomposition activities, temperature exposure, and high respiratory rate might also be attributed to high pH during th e dry season. Uchchariya and Saksena 2012 also obtained similar observations (Uchchariya et al. 2012). Variations in pH might influence pollution and nutrient solubility. In Pakistan, similar values of pH were also observed and reported by Qadir et al. 2008; Mahmood et al. 2014; Eqani et al. 2015. Another important ecological health indicator in the aquatic ecosystem is that the aquatic organisms utilize dissolved oxygen in respiration and biochemical reactions(Mustapha et al. 2008). The previous study shows that the DO data obtained was tolerable to support life in the aquatic environment during the whole year. (qadir et al. 2008; Kumar et al. 2012). Moreover, DO was exhibited above 4 mg/L in all samples of water in previous studies which is the minimum tolerable limit as per Chinese standard (3mg/L). According to findings reported from the Kra River Tehran (Iran), Indus River, Chocancharava River in Argentina, and Ebro River (Spain) variations in the level of DO was found to be comparable (Ali et al. 2004; Gholikandi et al. 2012; Bouza-Deaño et al. 2008; Gatica et al. 2012). Similarly, the low level of DO represents sewage addition to the water body as microorganisms decompose organic waste as food and, in return, utilizes oxygen present in water for their metabolic activities; hence they deplete DO level in the water (Staley et al. 1985; Sundaray et al. 2006). In the case of biological oxygen demand (BOD) indicates low temporal variations but considerable spatial variations. Biological oxygen demand (BOD) is the quantity of dissolved oxygen desired by aerobic organisms in water bodies to break down organic material found in a given sample of water at a specific temperature over a definite time and is considered as a significant indicator of water quality. Biological oxygen demand can be preferred over COD as it represents the biodegradable pollutants in the aquatic environment better (Ali et al. 2013). A high level of biological oxygen demand (BOD) produces an intolerable smell (Muralidharan et al. 2014). According to the standard set by China (1997), 6mg/L is the maximum permissible limit for aquatic organisms. It was found BOD in water samples exceeds the Chinese limit (6mg/L) for the propagation of aquatic organisms, emphasizing the fitness status of Streams water for aquatic life. So during the current study concentration of BOD were also comparable to those reported Gomati River, India (0.8–35.8 mg/L) and Pearl River in China (1.5-15.58 mg/L) (Zhang et al. 2009; Singh et al. 2005) and higher than those Kara River, Iran (5.6-11mg/L), Surma River, Bangladesh (3.5-7.6mg/L) and Mahanadi River, India (7.7–7.73) (Sundaray et al. 2006; Gholikandi et al. 2012; Alam et al. 2007).

In the freshwater stream system, natural flow regimes are a significant element for monitoring fish fauna assemblage (Church et al. 2002). Flow regimes are changed due to formations of water regulating structures like barrages and dams that critically impact biological activities in the aquatic ecosystem (Yoon et al. 2016). Furthermore, overfishing by using pesticides and illegal mesh size nets can significantly reduce fish fauna from some parts of the study area. However, increasing fishing pressure, pollution, habitat destruction, introduction of substituting exotic species, and other stress factors continue to exert strong pressure on fish populations around the world (Malakoff et al. 1997). Our study area is facing fishing pressure, pollution, destruction of habitat and many other factors that are causing decline in fish population.

Different environmental factors are responsible for the distribution of different fish species in different habitat (Fig. 4). The group of fishes shown in lower left corner has association with high pH, total dissolve substances (TDS), electrical conductivity (EC), and alkalinity. The fishes on the lower right corner are distributed on the basis of high temperature, alkalinity, bicarbonate and low oxygen content (BOD). However the fish species on the upper left and right corner are mostly non-specific.

Conclusion

Waste discharge from the industries and temperature of the air are two significant factor that influence the temperature of water. Higher temperature may not only increase the rate of metabolism in living organisms, but also impacts the photosynthesis and fish breeding. Fluctuations in the pH value of the water might be attributed to the anthropogenic stress in catchments like domestic sewage disposal, improper irrigation practices, weathering of the parent rock, and industrial discharge. The low level of DO represents sewage addition to the water body as microorganisms decompose organic waste as food and, in return, utilizes oxygen present in water for their metabolic activities; hence they deplete DO level in the water. Biological oxygen demand indicates low temporal variations but considerable spatial variations and it can be preferred over COD as it represents the biodegradable pollutants in the aquatic environment better. Practice of overfishing by using pesticides and illegal mesh size nets can significantly reduce fish fauna from some parts of the study area. Our study area is facing fishing pressure, pollution, destruction of habitat and many other factors that are causing decline in fish population. Different environmental factors like, BOD, COD, TDS, EC and alkalinity are responsible for the distribution of different fish species in different habitats of the study area.

Declarations

Ethical Approval: Ethical approval was received from the MUST University Ethical Institutional Review Board (IRB)

Consent to Participate: N/A

Consent to Publish : N/A

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Figures

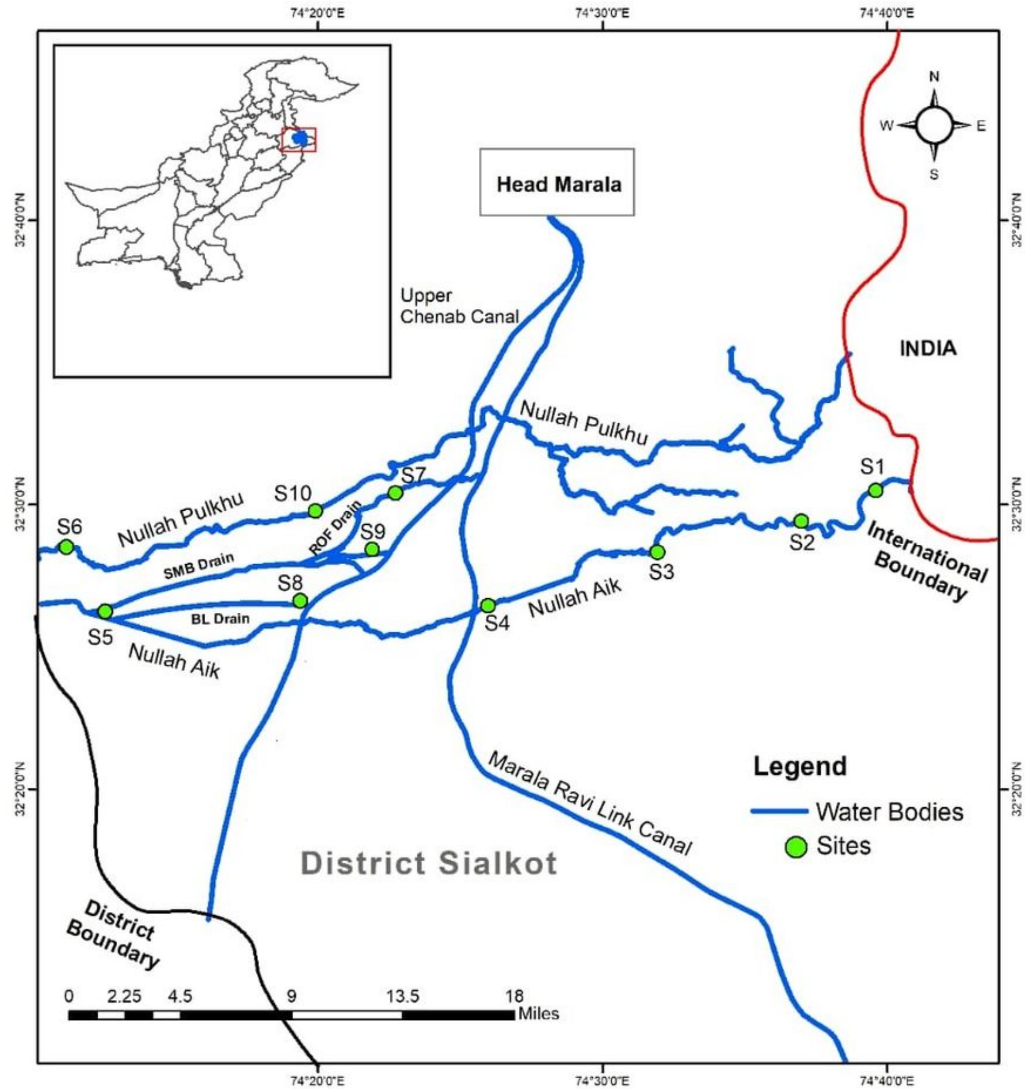

Figure 1

showing Nullah Aik, Nullah Palkhu (Tributaries of the River Chenab), and associated seasonal drains.

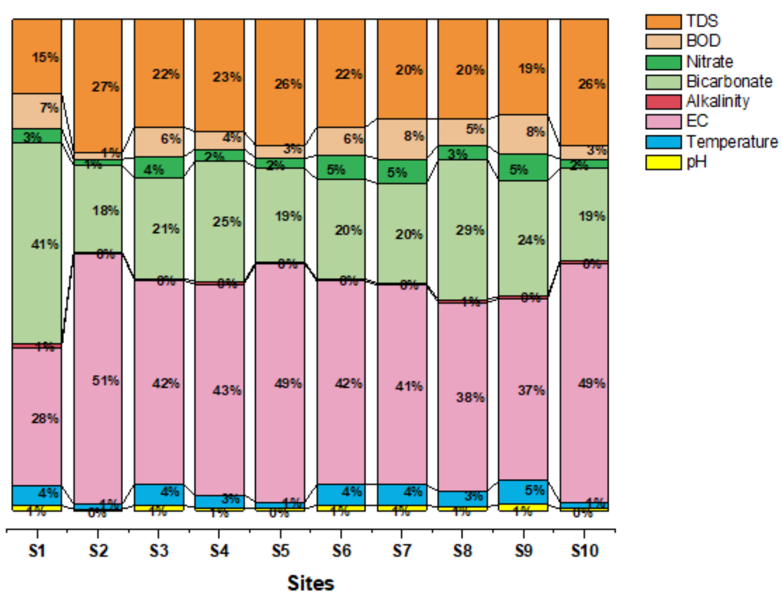

Figure 2

Percentage of water quality parameters in each site

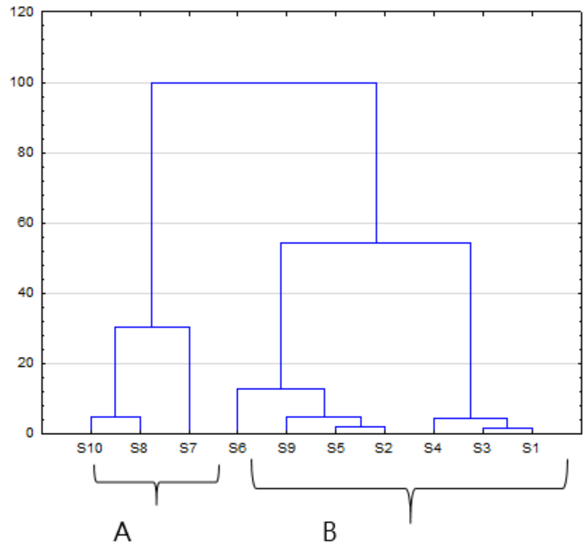

Figure 3

Dendrogram showing the site grouping on the basis of fish abundance

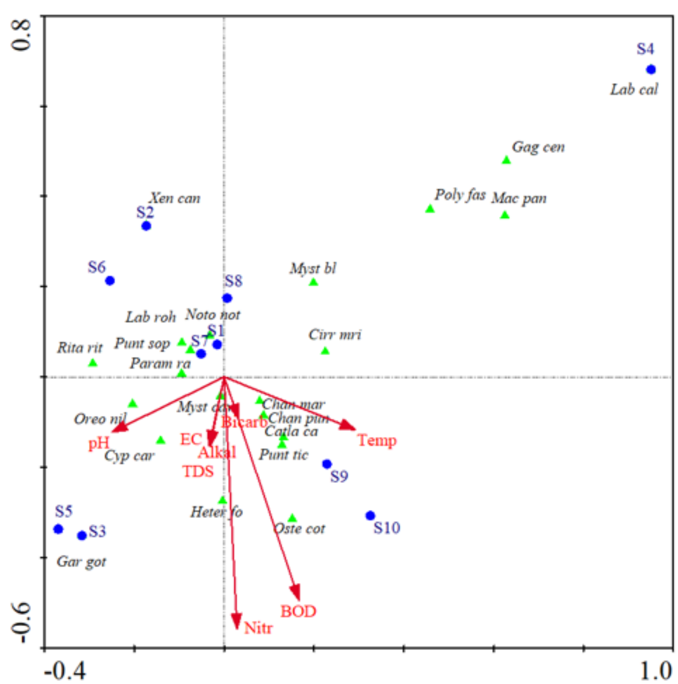

Figure 4

Relationship of environmental factors and distribution of fish species using CCA

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