www.biodicon.com Biological Diversity and Conservation

ISSN 1308-5301 Print; ISSN 1308-8084 Online BioDiCon 2/2 (2009) 110-124

Patterns and Distribution of Fish Assemblage in Nullah Aik and Nullah Palkhu Sialkot, Pakistan

Abdul QADİR [*1], Riffat Naseem MALİK [1], Tahira AHMAD [1], Arshed Makhdoom SABİR [2]

[1] Environmental Biology Laboratory, Department of Plant Sciences, Quaid-i-AzamUniversity, Islamabad, Pakistan
[2] Rice Research Intitute Kala Shah Kako, Punjab, Pakistan

Abstract

Nullah Aik and Nullah Palkhu, tributaries of Chenab River, Pakistan were studied to assess the impacts of environmental factors on diversity and distribution of fish species at 18 sites on, from September, 2004 to April 2006. A total of 1506 fish specimens were recorded from 14 sites whereas zero fish capture was recorded from four sites located in close vicinities of Sialkot city. Highest species richness and abundance diversity indices (Shannon and Simpson) were recorded during post monsoon season as compared to pre monsoon. In case of spatial distribution highest diversity indices were recorded from upstream site of Nullah Aik and down stream of Nullah Palkhu during post monsoon season. Most of the fish species were restricted to upstream of Nullah Aik during pre monsoon while rest of sites did not showed significant fish distribution. To evaluate the relationships between species abundance and environmental variables in longitudinal zones of streams, Canonical correspondence analysis (CCA) was used. Out of 13 variables such as stream morphology (Stream flow, depth and flow), physicochemical parameters (DO, COD, turbidity and NO_3^-) and metals (Na, Ca, Fe, Pb, Cr, Ni and Cu) used for the explanation of species distribution data Ordination analysis with the direct gradient technique of the CCA was performed to study the association of these environmental parameters to species composition. CCA identified overall three groups (upstream fishes, downstream fishes and evenly distributed fishes. Fish assemblage at upstream sites was comparatively stable through out the year; however, downstream of studied streams severely affected during pre monsoon. Present study is a major step in exploring the structure of fish assemblage in Nullah Aik and Nullah Palkhu. It would be helpful in efforts for protection and rehabilitation of habitat and conservation of fish assemblage at local and regional level.

Key words: Polluted streams, Fish communities, Diversity, River Chenab, Punjab

1. Introduction

The diversity and spatio-temporal distribution pattern of fish assemblage in stream is highly influenced by variations in lotic ecosystem (Taylor, 1997). These variations are resulted due to environmental factors inside the stream (Taylor *et al.*, 2006). In intermittent streams environmental variations are of great importance for fish assemblage as compared to continuously flowing streams (Pires *et al*., 1999). Environmental factors such as physiochemical parameters of water quality and habitat structure determine the structure and composition of fish assemblages inside the stream (Casatti *et al*., 2006; Aparicio *et al.*, 2000) and result in change of the ecological equilibrium (Lyons, 1996; Karr, 1986). Habitat structure and physiochemical quality of stream water have been widely used to explore the relationships with fish assemblage (Casatti *et al.*, 2006). Fishes aggregate into co-existing groups to form complex assemblages of species in pristine aquatic ecosystem (Lamouroux *et al*., 2002; Pusey and Kennard 1996). Association of different species in food web is a delicate and complex phenomenon that has evolved over long time period. Physical habitat and stream water quality are very sensitive to human pollution (Casatti *et al*., 2006). Aquatic communities, especially fishes reflect the intensity of degradation in streams and rivers (Das and Chakrabarty, 2007; Wichert and Rapport, 1998).

[*] *Corresponding author* / Haberleşmeden sorumlu yazar: aqfics@yahoo.com

Streams which experience irregular flow are more vulnerable to anthropogenic activities (Paul and Meyer, 2001) such as industrial effluents, municipal sewage, and surface runoff from urban and agricultural land, which alter the water quality and habitat structure of stream (Qadir *et al*., 2008; Singh *et al.,* 2005). Change in water quality due to untreated industrial effluent and municipal sewage not only increases the load of pollutants to streams but also put the fish fauna under stress (Davis *et al.,* 2003; Matthews, 1998).

Fish assemblages have been used as an indicator of environmental degradation (Arunachalam, 2000; Scott and Hall, 1997). Fish diversity in streams and rivers is considered as a diagnostic tool to highlight the impact of environmental changes (Das and Chakrabarty, 2007). Loss of fish species diversity determines the severity of habitat degradation of an aquatic ecosystem (Ganasan and Hughes, 1998).

Structure and composition of fish assemblage in temperate streams exhibit prominent temporal variations influenced by habitat characteristics and physico-chemical characteristics of water (Magalhães *et al*., 2002). The temporal distribution patterns of fish assemblages and water quality are directily or indirectly influenced by the flow regime (Godoy *et al.,* 2002; Grossman *et al.,* 1990). Most of the streams and rivers in oriental region exhibit high flow during monsoon season and experience low flow or drought during pre monsoon season, which determine the structure of fish communities in the streams (Pires *et al.,* 1999). Fish assemblages of such streams are adapted to low and high stream flow to attain ecological equilibrium in fish population. However, anthropogenic factors such as pollution load from industries and municipalities, water abstraction and introduction of alien species highly destabilize the equilibrium of fish assemblage (Pires *et al*., 1999). Unwise human activities in the catchment area deteriorate the water quality and disrupt the integrity of fish assemblage, which results, vanishing of native fish species or appearance of exotic species in an ecosystem (Lyons, 1996; Karr *et al*., 1986). Any change in species composition due to addition or deletion of species may disrupt the functional and functional integrity of an aquatic ecosystem (Lyons, 1996).

Influence of environmental factors on structure and function of fish assemblages in streams have been studied in several countries (Bhat and Magurran, 2007; Li and Gelwick, 2005; Akin et al, 2005; Bhat, 2004; Davis *et al.,* 2003; Magalhães *et al*., 2002; Gafny *et al.,* 2000; Belliard *et al.,* 1999; Snodgrass *et al*., 1996). Diversity indices and multivariate statistical techniques are commonly used to highlight the role of various important environmental factors that contributes in explanation of fish diversity and distribution along longitudinal gradients (Koel and Peterka, 2003). Multivariate techniques like Canonical correspondence analysis (CCA) provide information regarding current status of fish distribution in relation to environmental variables (Akin et al., 2005; Inoue and Nakano, 2001). Multivariate techniques have been useful in decision making for the restoration and management of degraded streams and to assess the impact of disturbance and identification of factors contribute in deterioration of stream ecosystem for effective stream management (Qadir and Malik, 2009; Paul and Meyer, 2001). Major restoration efforts for intermittent streams are underway in many parts of the world (Paul and Meyer, 2001) and restoration efforts have been successfully implemented. Unfortunately, in developing countries like Pakistan, no restoration efforts for streams and rivers have been made so far (Qadir, and Malik, 2009). Information related to role of environmental factors in shaping the distribution pattern of fishes in streams and rivers is completely lacking. It is important to collect baseline data about biotic (fish assemblage) and abiotic (environmental) components of stream/river ecosystem before taking any step towards restoration and management of a streams or rivers. The objectives of present study are:

- to assess the fish species diversity in Nullah Aik and Nullah Palkhu,
- to explain the pattern of spatio-temporal variations in diversity and composition of fish assemblage and

to explore the role of environmental variables in fish distribution.

2. Materials and methods

Present study was focused on Nullah Aik and Nullah Palkhu (32° 24′- 32°37′ N and 73°59′- 75°02′E) tributaries of river Chenab (Figure 1). These streams run parallel from east to west wards and join each other before falling in Chenab River at Wazirabad city in District Gujranwala. The average annual precipitation in there catchments area is 950 mm and major share of rains is received during the monsoon period. Most of the floods follow resulting in deposition of new alluvial soil in catchment areas, which come from sediment of Pir Pangal Range to flat plains of upper Rachna Doab (Region between river Chenab and Ravi).

Climate of the region is mainly sub-tropical with a well defined by rainy season between (July to September), autumn (October and November), winter (December and February),short spring (March and April) and a relatively dry pre-monsoon (summer betweenMay and June). The catchment area of Nullah Aik and Nullah Palkhu is the part of upper Rachna Doab (Region between River Chenab and Ravi). The great plain of Punjab started from the upper parts of Rachna Doab with an average slope (0.37 m/km), which gradually decrease from North East to South West (Jehangir et al., 2002). The upper part of Punjab plain originated during late Pleistocene alluvial deposition from Lesser Himalayas, which is approximately 200meter thick (Greenman et al., 1967). The soil is predominantly alluvial of varying textural classes such as clay and silt loam while sandy loam and sandy clay loam also prevail in the region.

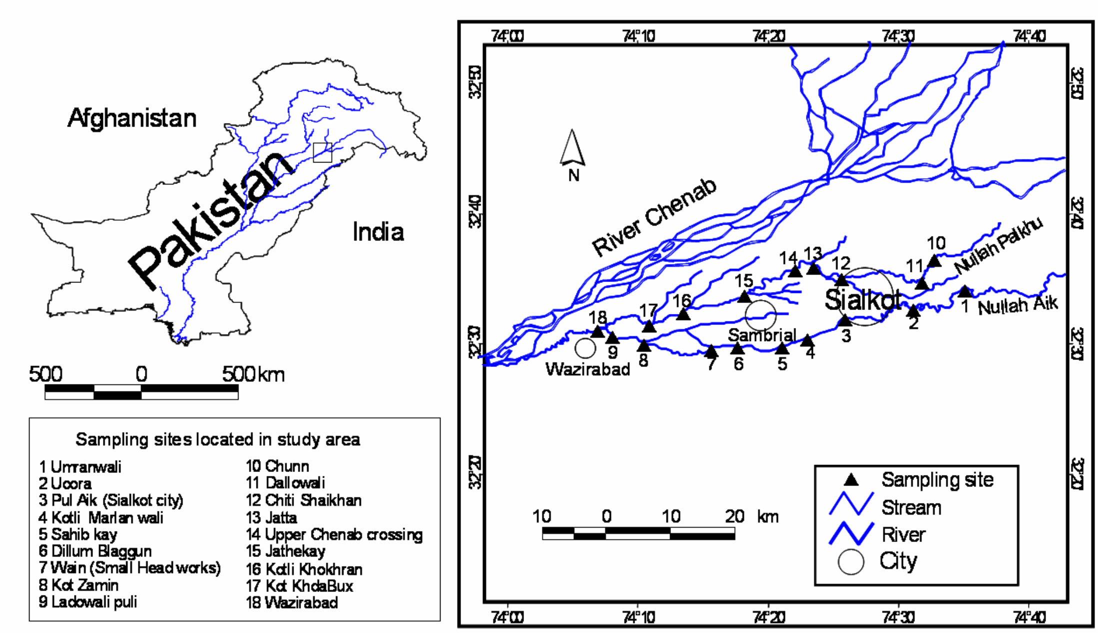


Figure 1. Map of study area showing sampling sites located on Nullah Aik and Nullah Palkhu; tributaries of River Chenab, Pakistan

Nullah Aik receives water from springs in eastern parts of Jammu district and from heavy rains in its upper catchment area. The resource utilization of Nullah Aik and Nullah Palkhu started 5000 years ago in Vedic Era, when Raja Sáliváhan founded the Sialkot named as Sakala (Population and Censes organization, 2000). Raja Sáliváhan and his son (Raja Rasálu) invited the people from various parts of Northern India to come and settle in Sialkot.

Nallah Aik and Nullah Palkhu which have been subjected to severe alterations of their habitat and in some localities deterioration of water quality is at the rise due to the industrial effluent and municipal waste from their catchment areas (Qadir and Malik, 2009). Eighteen sampling sites were selected on Nullah Aik and Nullah Palkhu based on the expected level of impairment from industrial and municipal waste. Sampling was conducted for post monsoon and pre monsoon seasons from September, 2004 to July 2005. Thirteen water quality variables (stream morphology, physiochemical and metal contents) were analysed as described by Qadir *et al.* (2008).

Fish samples were collected from each site using variety of fishing nets of varying mesh sizes as suggested by Bhat (2003). All sampling sites were intensively sampled in an effort to capture as many fish species as possible in proportion to their abundance (Matthews, 1985). Captured fish specimens were transferred immediately into stream water filled tubs place on stream bank to reduce the chances of fish mortality. Maximum five specimens of each species were packed, labelled in separate polythene bags, placed in icebox and transported to laboratory within 12 hours for the purpose of identification and further chemical analysis (Van Aardt & Erdmann, 2004). The remaining specimens were released back into stream water at the same point from where fish was captured (Ganasan & Hughes, 1998). Released fishes were only native, whereas, exotic fishes were not returned back to the stream. The juvenile fishes, which have tail length less than 20mm, were excluded because of inadequacy in their capturing (Helms *et al.*, 2005). Taxonomic identification and classification was done on the basis of morphometric characteristics up to the species level. Fish species were identified following regional keys (Mirza & Bhatti, 1993; Mirza, 2003; Talwar & Jhingran, 1991; http://www.fishbase.org).

Shannon index (H´) and Simpson index (D) were used to calculate fish species diversity (Lima-Junior, *et al*., 2006; Magurran, 1991) at different sampling sites during post and pre monsoon seasons.

CCA which is a direct gradient analysis was used to highlight the relationship between fish distribution and environmental variables (Malik and Hussain, 2008). CCA is an eigenvalue based technique applied on species abundance data in relation to environmental variables (stream morphology, physiochemical and metal concentration) during post monsoon and pre monsoon seasons at 18 sampling sites located on Nullah Aik and Nullah Palkhu. Strongly correlated variables were excluded from this analysis using Pearson correlation and 13 variables were used (Pires *et al*., 1999). Environmental variables viz; stream morplogy (stream flow, depth and width), physiochemical variables (DO, COD, turbidity and NO_3^-) and six metals (Na, Ca, Fe, Pb, Cr and Cu) were subjected to CCA. The sites representing zero fish catch were also excluded from CCA. Two separate CCAs were performed on fish abundance data with environmental data sets recorded during post and pre monsoon season (Ter Braak and Verdonschot, 1995). First CCA was applied to find out the relationship between (a) sites and environmental variables (14 sites x 13environmental variables) and (b) between species and environmental variables (24 species x 13environmental variables) for post monsoon. CCA for pre monsoon season was performed on site matrix including 12 sites and x 13 environmental variables and species matrix which included 17 x 13 environmental variables (Eggleton, 2004; Malik and Hussain, 2008). Monte Carlo permutation test with 1000 permutations was performed to check wheather environmental parameters were significancantly correlated with fish species composition of plots (Pires *et al.*, 1999). For Fish diversity analysis and CCA, Multivariate Statistical Package (MVSP) was used (Kovach, 1999).

The coefficient of community loss depict the range of scenarios to measure the intensity of change caused by pollution which is a useful tool to take decision for the management of species diversity in an aquatic ecosystem was calculated using following formula as described (Wright & Welbourn, 2002; Courtemanch & Davis, 1987):

$$l = (a-c)/b$$

where (1) is coefficient of community loss, (a) total number of texa from polluted section, (b) total number of texa from unpolluted section and (c) number of texa common in polluted and unpolluted zones.

3. Results

A total of 1506 individuals of 24 species (Table 1a & b) belonging to 12 families and 19 genera were recorded in two seasons (post monsoon and pre monsoon) from Nullah Aik and Nullah Palkhu (Table 1a and b). About 50.6% of individuals belonged to ten species of family Cyprinidae followed by 19.6% of individual of *Channa punctata* belonging to family Channidae. The remaining 29.8% of relative abundance was contributed by family Bagridae (8.7%), Heteropneustidae (6.7%), Ambassidae (2.7%), Notopteridae (2.3%), Siluridae (2.3%), Osphronemidae (1.7%), Mastacembelidae (0.1%) and Sisoridae (0.1%). The highest species richness and abundance was recorded in post monsoon after rainy season, whereas, lowest in pre monsoon before rainy season.

During post monsoon season, 1141 fish specimens were captured from 14 sites. Maximum species richness (14), Simpson (2.29) and Shannon diversity index (0.86 and 0.88) were recorded from upstream sites (1 and 2) of Nullah Aik, which decrease to zero at sites located in close vicinity of Sialkot city. Fish species reappear in far downstream of studied stream (Fig 2). *Channa punctata* and *Puntius sophore* species were the dominant species recorded from 12 sites (Table 1b).

A total of 375 fish specimens were captured from 12 sites during pre monsoon. None of fish was recorded from six sites (3, 4, 5, 12, 13 and 14). Maximum species richness (13) was recorded at site 2 located at upstream of Nullah Aik with Simpson (2.19) and Shannon (0.85) diversity indices and *Channa punctata* and *Puntius ticto* were recorded in high abundance from nine and eight sampling sites, respectively (Fig 2).

Changes in Species Composition along longitudinal Gradient and Distributional Patterns of Feeding Guilds

Four trophic groups of fishes were identified viz; invertivores, herbivores, omnivores and carnivores from studied streams. Relative abundance for different feeding groups recorded from Nullah Aik was in order: invertivores 36.2% > herbivore 24.6 > Carnivore 24.0% > omnivore 15.1%, whereas, Nullah Palkhu exhibited different trend: Carnivore 44.9 % > invertivores 36.5% > omnivore 11.3% > herbivore7.3%.

Invertivore fishes were generally small sized fishes, which mainly feed on insect larvae and other small invertebrates. Among invertivores, two species (*Puntius ticto* and *Puntius sophore*) were found as ubiquitous species in upstream and downstream sites, whereas, *Osteobrama cotio* and *Parambassis ranga* showed restricted distribution in upstream of Nullah Aik. *Polyacanthus fasciatus,* which an invertevore species was distributed from upstream and downstream of Nullah Palkhu, whereas, no specimen of this species was captured from Nulluh Aik. Five herbivore fish species were sampled throughout the study area. Two species (*Labeo calbasu* and *Labeo dero*) were restricted in upstream of Nullah Aik, whereas, other three species (*Labeo rohita, Cirrhinus reba* and *Cirrhinus cirrhosus)* were ubiquitous in upstream and downstream of studied streams. Omnivore trophic group of fishes was consisting of four species. Out of these, two species (*Oreochromis niloticus* and *Salmostoma bacaila*) were common in up and downstream sites but preferably present in upstream sites. One omnivore species (*Garra gotyla*) was restricted to downstream of Nullah Aik, whereas, *Heteropneustes fossilis* was common in downstream of Nullah Aik and Nullah Palkhu. The largest trophic guild was carnivore species consisting of nine fish species. Among these carnivore species, *Channa punctata, Mystus cavasius, Rita rita* and *Wallago attu* were distributed in upstream and downstream of Nullah Aik and Nullah Palkhu. *Sperata seenghala* and *Xenentodon cancila* were distributed at upstream sites, whereas, *Mastacembelus armatus, Gagata cenia* and *Notopterus notopterus* were restricted in downstream of Nullah Palkhu.

The relative abundance of feeding groups of fish in up and downstream of streams in post monsoon and pre monsoon is given in Table 2. Among these feeding groups, maximum relative abundance of herbivores (54.2%) captured from upstream of Nullah Aik, whereas, no herbivorous species was recorded from downstream of Nullah Aik and Palkhu during pre monsoon season. Highest relative abundance of invertivores (57.4%) was recorded from downstream of Nullah Palkhu during pre monsoon. Insectivorous individuals were more abundant in upstream during post monsoon, whereas, abundant in downstream sites during pre monsoon. Highest relative abundance of omnivores (21.6%) was observed in downstream of Nullah Aik during pre monsoon season. Carnivore species were more abundant in downstream zone throughout the sampling period.

Table 1. Richness (S), evenness (E), Simpson’s diversity (H) and Shannon diversity (D) indices of (a) site and (b) fish species from Nullah Aik and Nullah Palkhu

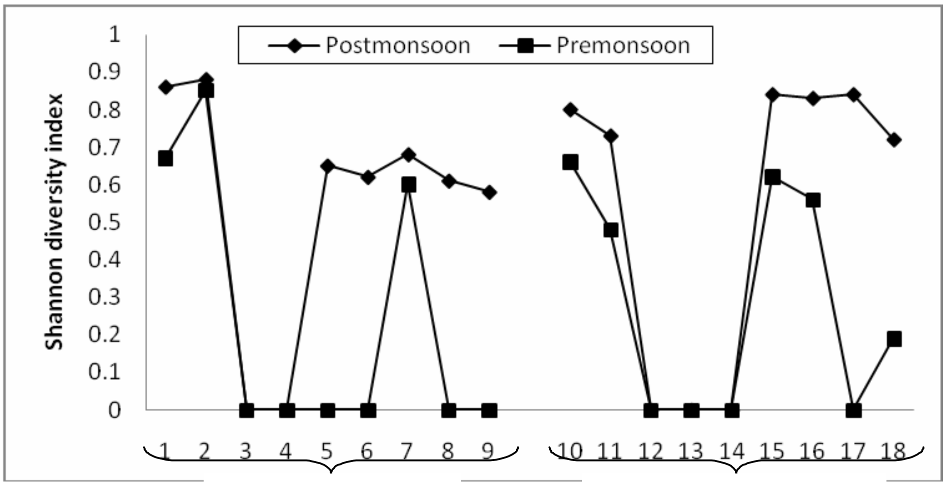
(a)

Season	**Post monsoon**			**Pre monsoon**		
Site #	**S**	**H**	**D`**	**S**	**H**	**D`**
1	14	2.20	0.86	8	1.4	0.67
2	14	2.29	0.88	13	2.19	0.85
5	4	1.22	0.65	0	0	0
6	4	1.15	0.62	1	0	0
7	7	1.47	0.68	3	0.99	0.60
8	3	1.01	0.61	1	0	0
9	4	1.09	0.58	1	0	0
10	7	1.76	0.80	4	1.23	0.66
11	5	1.39	0.73	2	0.68	0.48
13	1	0	0	0	0	0
15	13	2.16	0.84	3	1.02	0.62
16	10	1.99	0.83	3	0.9	0.56
17	12	2.10	0.84	1	0	0
18	5	1.39	0.72	2	0.34	0.19

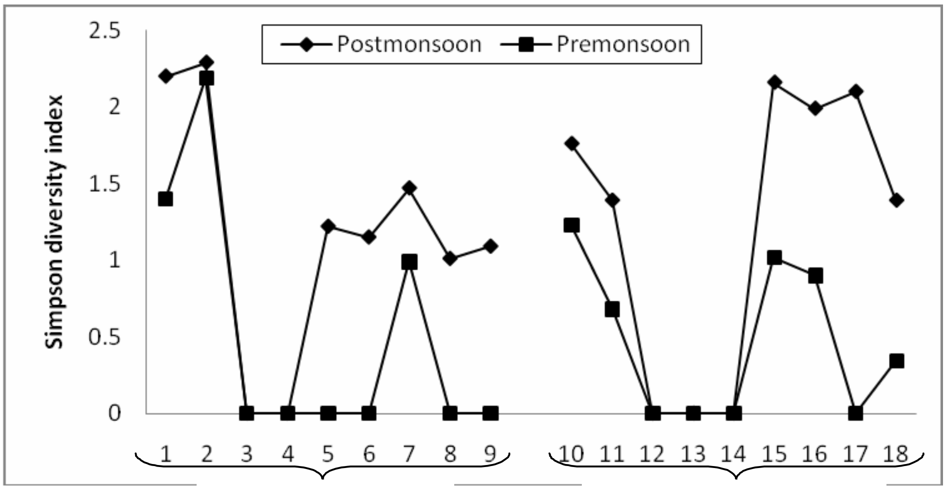
(b)

Family	Species	Post monsoon			Pre monsoon		
		S	H	D`	S	H	D`
Ambassidae	*Parambassis ranga*	2	0.29	0.15	1	0	0
Bagridae	*Mystus cavasius*	7	1.73	0.80	2	0.66	0.47
	Rita rita	4	1.32	0.72	1	0	0
	Sperata seenghala	2	0.56	0.37	0	0	0
Belonidae	*Xenentodon cancila*	2	0.63	0.44	1	0	0
Channidae	*Channa punctata*	12	2.17	0.86	8	1.69	0.78
Cichlidae	*Oreochromis niloticus*	5	1.30	0.68	2	0.38	0.22
Cyprinidae	*Cirrhinus cirrhosus*	5	1.49	0.75	1	0	0
	Cyprinus carpio	5	1.46	0.74	0	0	0
	Cirrhinus reba	1	0	0	3	0.80	0.49
	Garra gotyla	1	0	0	0	0	0
	Labeo calbasu	1	0	0	1	0	0
	Labeo dero	1	0	0	1	0	0
	Labeo rohita	4	1.18	0.64	2	0.58	0.39
	Osteobrama cotio	2	0.69	0.49	1	0	0
	Puntius ticto	11	2.22	0.87	9	2.06	0.85
	Puntius sophore	12	2.29	0.88	4	1.11	0.59
	Salmostoma bacaila	2	*0.59*	*0.40*	*2*	*0.41*	*0.24*
Heteropneustidae	*Heteropneustes fossilis*	7	1.69	0.79	2	0.69	0.49
Mastacembelidae	*Mastacembelus armatus*	1	0	0	0	0	0
Notopteridae	*Notopterus notopterus*	4	1.27	0.69	0	0	0
Osphronemidae	*Polyacanthus fasciatus*	4	1.30	0.71	0	0	0
Siluridae	*Wallago attu*	7	1.77	0.81	1	0	0
Sisoridae	*Gagata cenia*	1	0	0	0	0	0

(a)



(b)



(c)

Figure 2. (a) Species richness, (b) Shannon diversity Indices and (c) Simson diversity indices recorded from various sites recorded from Nullah Aik and Nullah Palkhu

Environmetal Relationship of Fish Assemblage during post monsoon and pre monsoon

CCA was applied on 13 significant environmental variables to highlight their relationship with distribution of fish during post monsoon and pre monsoon in studied streams. The ordination plot of site and species scores produced from CCA shows the distribution of sites and species in ordination (Figure 3 and 4).

Table 2. Relative abundance of different feeding group in up and downstream of Nullah Aik and Nullah Palkhu

Season	**Sampling zone**	**Feeding group (%)**			
		Carnivore	Herbivore	Invertivore	Omnivore
Post monsoon	Upstream of Nullah Aik	20.2	16.8	49	14
	Downstream of Nullah Palkhu	46.7	6.1	28	19.2
	Upstream of Nullah Palkhu	34.3	8.7	54.7	2.1
	Downstream of Nullah Palkhu	49.4	7.4	28.4	14.8
Pre monsoon	Upstream of Nullah Aik	8.5	54.2	25.5	11.9
	Downstream of Nullah Palkhu	56	0	21.6	21.6
	Upstream of Nullah Palkhu	52.5	10	37.5	0
	Downstream of Nullah Palkhu	27.7	0	57.4	14.8

Post Monsoon

First three axes of sites ordination for post monsoon accounted 51.38% of total variance with more than 0.1 eigenvalues (Table 3a). First axis explained about 29.94 % of the total variations with 0.4 eigenvalue and was correlated to COD (r = 0.59), Pb (r = 0.51) and DO (r = -0.90). Axis 2 descibed 11.6 of the total variations with 0.15 eigenvalue was correlated to stream width (r = 0.67), Cr (r = 0.59) and stream depth (r = 0.75) (Table 3b).

CCA ordinations for sampling sites during post monsoon season are given in Fig 4a-d). The sampling sites located at upstream of Nullah Aik and Nullah Palkhu were closely associated and grouped together on the left side of CCA axis 1. Furthermore, sampling sites located in downstream of Nullah Aik and Nullah Palkhu on the right side of CCA axis 1. The sites located in downstream of Nullah were found to be closely associated with each other and showing the similar composition of fish assemblages, whereas, sites located at downstream of Nullah Aik were dispersed on right side of CCA axis 1. These dispersed sites indicate variations in composition of fish assemblages of sites. Therefore, sites located close to each other on CA plot exhibit the same fish species composition than sites located far from each other and showed differences in fish species composition. Stream flow, stream width, DO and NO_3^- and Pb were associated with upstream site of Nullah Aik and Nullah Palkhu, whereas, stream depth, COD, Na, Ca, Fe, Cr and Cu were related with downstream of Nullah Aik and Nullah Palkhu.

CCA species ordination (species x environment) identified three different groups of fish species for post monsoon (Figure 4c-d). Group 1 comprised of species, which were dwelling in upstream site consisting of seven species (*Parambassis ranga, Labeo rohita, Labeo dero, Labeo calbasu, Osteobrama cotio, Xenentodon cancila* and *Sperata seenghala*) highly correlated to DO, NO_3^- and stream flow. Out of seven, five species (*Parambassis ranga, Labeo rohita, Labeo dero, Labeo calbasu* and *Osteobrama cotio*) belonged to family Cyprinidae, whereas, remaining two *Xenentodon cancila* and *Sperata seenghala* represented the families Belonidae and Bagridae, respectively. Ten species (*Cirrhinus reba, Cirrhinus cirrhosus, Puntius sophore, Puntius ticto, Salmostoma bacaila, Mystus cavasius, Rita rita, Channa punctata, Oreochromis niloticus* and *Wallago attu*) were widely distributed in upstream and downstream and clustered in group 2. Among these species, species such as *Cirrhinus reba, Cirrhinus cirrhosus, Puntius sophore, Puntius ticto and Salmostoma bacaila* were represented by family Cyprinidae, whereas, *Mystus cavasius* and *Rita rita* belonged to family Bagridae. Remaining four species viz; *Channa punctata, Oreochromis niloticus* and *Wallago attu* belonged to families viz; Channidae, Cichlidae and Siluridae, respectively. These species were ubiquitous in upstream and downstream and located at the centre of the biplot (Figure 4c and d). Group 3 was represented by *Cyprinus carpio, Garra gotyla, Heteropneustes fossilis Mastacembelus armatus, Notopterus notopterus* and *Gagata cenia* belonged to Cyprinidae, Mastacembelidae, Notopteridae and Sisoridae, which were distributed in downstream sites and absent at upstream sites. Species belonging to third group were tolerant to COD, turbidity, Na, Ca, Fe, Pb, Cr and Cu.

Pre Monsoon

CCA plot ordination of pre monsoon season explained about 37.48% of the total variation for first three axes with more than 0.1 eigenvalues (Table 3a). First axis explained 37.5% variation with 0.68 eigenvalue and positively correlated with stream flow (r = 0.56), turbidity (r = 0.65), nitrates (r = 0.66), Na(r = 0.82) and Cr (r = 0.86), whereas, negative with DO (r = -0. 90). Second axis contributed about 20.30% of the total variations with 0.36 and negatively correlated with stream flow (r = -0.75) and nitrate (r = -0.55). COD (r = -0.65) exhibited positive correlation with third axis that explained about 12.9 % variation with 0.23 eigenvalue (Table 3b).

CCA plot ordination for pre monsoon, sites located at upstream of Nullah Aik were grouped together on the left side of CCA axis1 and were strongly influenced with Stream flow, DO and NO_3^-. Sites located in upstream of Nullah Palkhu, downstream of Nullah Aik and Palkhu were plotted on right side of CCA axis 1. The upstream sites of Nullah Aik were correlated with stream width, DO and NO_3^- . Stream depth, flow, COD, turbidity, Na, Ca, Fe, Cr and Cu were related to downstream sites of studied streams.

CCA species ordination provides pattern of fish assemblage (Figure 4c and d). Three clusters of fish species were recognized. First group was represented by nine species of upstream sites (*Cirrhinus cirrhosus, Cirrhinus reba, Labeo dero, Labeo calbasu, Labeo rohita, Osteobrama cotio, Parambassis ranga, Xenentodon cancila,* and *Wallago attu).* Out of nine species, six species (*Cirrhinus cirrhosus, Cirrhinus reba, Labeo dero, Labeo calbasu, Labeo rohita* and *Osteobrama cotio)* were represented by family Cyprinidae, whereas, remaining four species (*Parambassis ranga, Xenentodon cancila* and *Wallago attu*) belong to families Ambassidae, Belonidae and Siluridae, respectively. These species were positively correlated with stream width, DO and NO_3. Second group comprized of three species (*Channa punctata, Puntius sophore* and *Puntius ticto),* which was evenly distributed in up and downstream sites. Third group was represented by one fish species (*Heteropneustes fossilis*), which belongs to family Heteropneustidae restricted in downstream sites. Fish species showed correlation with COD, turbidity, Na, Ca, Fe, Pb, Cr and Cu. CCA plot for pre monsoon season differ from pre monsoon. The upstream fish species did not show significant variation, whereas, significant reduction in fish species richness in second group (ubiquitous species) and in third group (downstream cluster) during pre monsoon. However, species in first group showed an increase in number of species and restricted to upstream area during pre monsoon season.

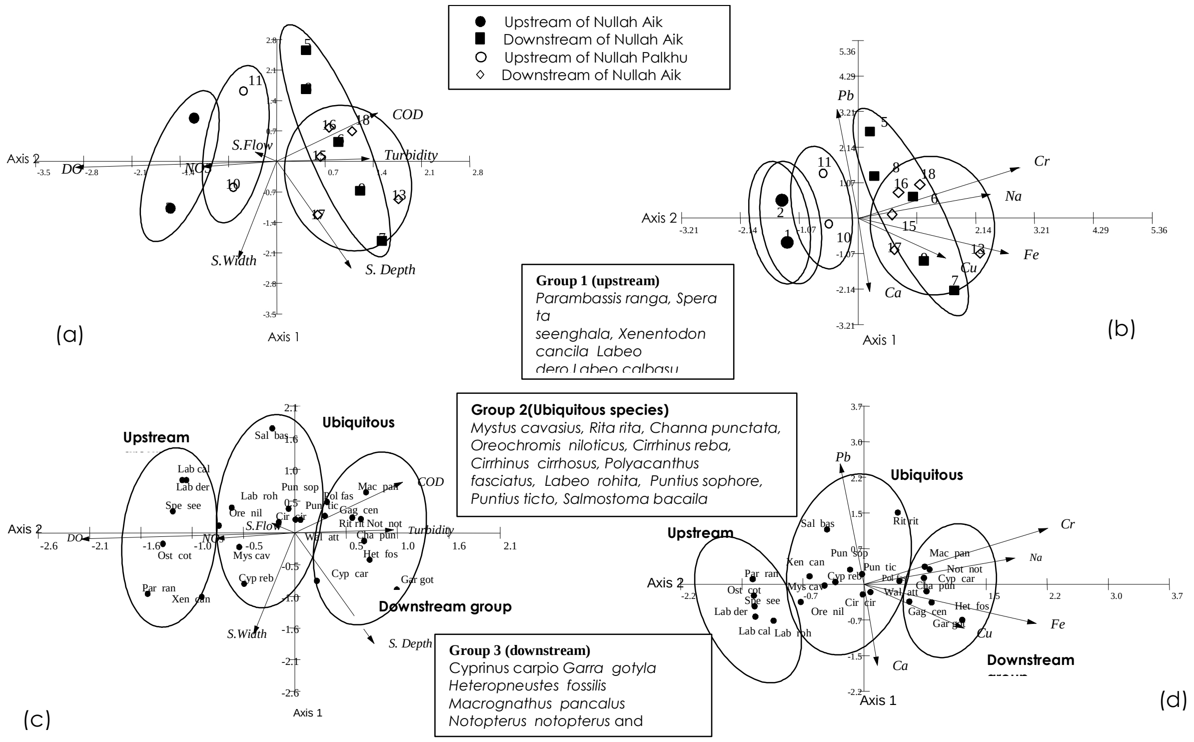


Figure 3. Canonical correspondence analysis (CCA) plots showing site scores (a &b) and species (c &d) and effect of environmental factors on fish assemblages during postmonsoon

4. Discussion

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). Poor water quality is one of the important factor, which has been reported to alter abiotic and biotic component of intermittent streams (Davis *et al*., 2003; Moses and Morris, 1998). During present study, studied streams are facing natural and anthropogenic disturbances. Natural disturbances are mainly based on climatic and geomorpholoical factors such as stream flow, depth, width and rainfall pattern in the catchment area, whereas, discharge of industrial effluents and municipal sewage are resulted due to human activities, which remain throughout the year. During present study, major changes in fish assemblage were resulted due to discharge of industrial effluents and municipal sewage from Sialkot city. The severe impacts of anthropogenic activities were observed at sites (3, 4, 12 and 14) located in close vicinity of Sialkot, where no fish specimen was captured. The continuous human stress on streams can completely vanish the whole fish fauna, whereas, pristine streams exhibited little variations in fish assemblage over long time period (Paller, 2002).

Deterioration of water quality due to anthropogenic activities has contributed in replacement and disappearance of sensitive fish species in streams and rivers (Karr *et al*., 1986). Degradation of water quality increases stress on fish assemblage that reduces species diversity and abundance (Pollino *et al*., 2004). Boët *et al*. (1994) and Belliard *et al*. (1999) highlighted that water quality degradation in downstream of urban stream, profoundly affects distribution and movements of fishes. Extinction or missing of any species provokes the ecological disturbance at the community as well as ecosystem level. During present study, fish assemblage in upstream of Nullah Aik was stable in post monsoon and pre monsoon season, whereas, fish assemblage in upstream of Nullah Palkhu became affected due to reduced stream discharge, which reduce the diversity of fishes during pre monsoon. The fish assemblage in downstream of Nullah Aik and Nullah Palkhu are severely affected from increased level of pollutant in stream water (Qadir and Malik, 2009). Highest fish diversity was recorded at upstream sites of Nullah Aik during post monsoon. In upstream of studied streams, 18 fish species (*Parambassis ranga, Sperata seenghala, Xenentodon cancila Labeo dero, Labeo calbasu, Osteobrama cotio, Mystus cavasius, Rita rita, Channa punctata, Oreochromis niloticus, Cirrhinus reba, Cirrhinus cirrhosus, Polyacanthus fasciatus, Labeo rohita, Puntius sophore, Puntius ticto, Salmostoma bacaila* and *Wallago attu)* were captured and species diversity reduced to 13 fish species (*Cirrhinus cirrhosus, Cirrhinus reba, Labeo dero, Labeo calbasu, Labeo rohita, Parambassis ranga, Xenentodon cancila, Wallago attu, Channa punctata, Puntius sophore, Puntius ticto* and *Osteobrama cotio*) in pre monsoon. Highest variations in species richness were recorded in downstream of Nullah Palkhu.

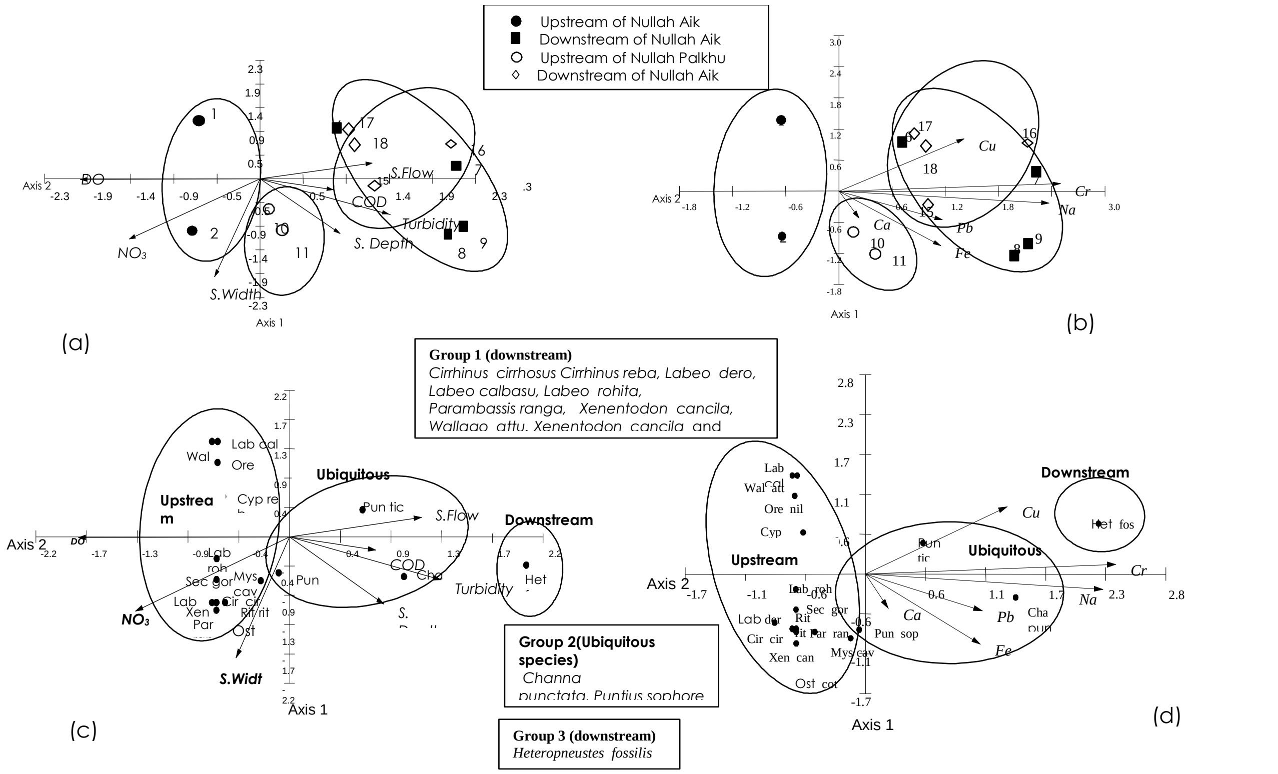


Figure 4. Canonical correspondence analysis (CCA) plots showing site scores (a & b) and species (c & d) and effect of environmental factors on fish assemblages during premonsoon

Eighteen fish species were recorded in downstream during post monsoon, whereas, only four fish species (*Channa punctata, Puntius sophore, Puntius ticto and Heteropneustes fossilis*) were recorded from down stream. Similarly, Paul and Meyer (2001) and Gafny *et al.* (2000) reported significant reduction in fish diversity during dry season at close downstream sites of cities. Decline in fish diversity and abundance become more pronounced in downstream of towns and cities, however, the relative abundance of tolerant taxa increases in moderately disturbed downstream (Paul and Meyer, 2001). In response to pollution, sensitive species disappear sharply, whereas, individuals of tolerant fish species can continue to exist in polluted water up to some extent (Gafny *et al.,* 2000).

Gradual increase in species richness and distribution of fish assemblage, from upstream to downstream have been reported in pristine streams and rivers (Lima-Junior *et al*., 2006; Bhat, 2004), however, in intermittent streams, species richness decreases with increase in anthropogenic activities (Paul and Meyer, 2001). The results showed that Nullah Aik has maximum diversity in upstream region that reaches to its ebb (zero fish catch) at sampling sites (3 and 4) near to Sialkot city, which receive high pollutant load from industries and municipalities. In downstream of Nullah Aik, some species like *Channa punctata, Puntius sophore* and *Wallago attu* reappear to establish fish assemblage. According to Bhat (2004) and Bhat and Magurran, (2007) natural streams become modified due to municipal and industrial effluents as well as construction of barriers for divergences of water. Presence of small head works at site 7 (Wain) is also an important reason for reduction of the fish diversity in downstream. Stream water of Nullah Aik is diverted into sub-channels and hundreds of pumps have been established on stream banks to suck stream water for the irrigation purpose. Reduced of stream flow at downstream of Wain cannot support fish assemblage to re-establish, resulting less diversity in downstream of Nullah Aik.

Streams and rivers exhibit changes in distribution of different feeding groups along longitudinal gradient (Bhat, 2004). High relative abundance of herbivore species in upstream was due to presence of algae and other aquatic plants on which these species feed. During pre monsoon season, herbivore fishes shift towards upstream segment due to high load of pollutants in downstream segment. According to Ganasan and Hughes (1998) herbivore species are sensitive as compared to invertivore, which disappears as pollution stress increases. Bhat (2004) also reported that insectivorous species are ubiquitous in upstream and downstream of rivers. The results indicated seasonal variations in distribution of invertivore species. Hoyt *et al*. (2001) reported that concentration of specific feeding guild at upstream or downstream depends upon the feeding and reproductive activities. Omnivores and carnivores were found in up and downstream but preferably present at downstream sites. Bhat (2004) calculated higher relative abundance of carnivore in downstream sites. Generally, carnivore species are sensitive and respond to any change in water quality. However, carnivore species are also tolerant like *Channa punctata* can survive in unfavaourable conditions by developing some adaptation to survive in turbid condition and low level of oxygen (Narayanan and Khan, 1995; Anctil and Ali, 1976).

Streams exhibited great variations in stream morphological conditions influenced by stream size and discharge (Vlach *et al*., 2005). Stream morphological parameters include water 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). Bhat (2004) showed stream depth is correlated with species richness in the stream of Western Ghat, India. Stream depth and width contributes in structuring the fish assemblage (Lima-Junior *et al*., 2006). 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 (Jackson *et al.,* 2001a; Angermeier and Winston, 1998). During present study, maximum depth was observed during post monsoon while minimum in pre monsoon season due to variations in stream discharge. Stream sites exhibited depth ranged from 0.5 - 2.0m except, site 7.

Stream flow highly influences chemical properties of water and community patterns of fishes (Reash and Pigg, 1990). The structure of fish assemblage is characterized by the fluctuation in stream flow that is influenced by rainfall in the catchment area (Fraser, 1997; Castillo-Rivera *et al*., 2002). Stream flow has significant effects on species composition, diversity and reproduction (Xenopoulos *et al*., 2005). Regular stream flow provides better conditions for stability of fish communities. Low stream flow causes reduction in diversity of fishes in intermittent streams (Thompson and Larsen, 1994). Lowest stream flow rate was recorded in upstream of Palkhu during summer season. Reduction in stream flow affects the species richness and diversity in upstream of Nullah Palkhu and during dry period, fishes restrict to ditches and small pools. These ditches and small pools act as refuge sites, when water flow re-establishes in streams, fishes proliferate to maintain their population (Pires *et al*., 1999). Only four species (*Channa punctata, Puntius sophore, Puntius ticto* and *Heteropneustes fossilis*) were collected from downstream sites, which can survive at low level of DO. *Cirrhinus cirrhosus Cirrhinus reba, Labeo rohita, Wallago attu* and *Osteobrama cotio)* were common species in upstream and downstream during post monsoon but restrict themselves in upstream due to input of pollutants in pre monsoon. Streams flow with highest discharge level due to heavy rains in the catchment area during monsoon season. High stream water flow dilutes concentration of pollutants and allows the fish to move from river to upstream for spawning and breeding. Movement of fishes from river to streams during monsoon facilitates the re-colonization of fish species in upstream region. After monsoon season catchment area experiences dry spell resulting reduced stream. High discharge of pollutants from industries and urban sewage acts as barrier, which restrict the sensitive fishes in upstream sites.

DO is one of the important variable in explaining the distribution of species (Fraser, 1997; Castillo-Rivera *et al*., 2002). Depletion of DO makes the habitat unsuitable for fish life (Slavík and Bartǒs, 2001). In streams and rivers, DO define the pattern of fish assemblage on temporal and spatial scale (Mathews and Berg, 1997). DO play a vital role in all developmental stages of fish from embryo to adult (Thompson and Larsen, 1994). Low concentration of DO (below 4mg/L) causes reduced growth rate increases the risk of disease and even death (Thompson and Larsen, 1994). Level of DO (2.0 mg/L) in aquatic ecosystem is the minimum level to prevent the mortality of fish Abegaz *et al*. (2005). Intolerant species cannot withstand extreme fluctuations of DO. In disturbed stream; sensitive fishes disappear first or shift to least disturbed conditions. Disappearance of sensitive species creates the space for tolerant and exotic species to proliferate in such streams. The results showed that sites with less amount of DO were least diverse. Depletion of DO is mainly caused by organic pollution resulting in the process of decomposition of organic component inducing instability of DO concentration (Slavík and Bartǒs, 2001) and cause high COD value. High COD values determine chemical and organic pollution that severely affect the fish assemblage (Gafny *et al.,* 2000).

High turbidity level was recorded at downstream sites due to discharge of untreated effluents and sewage from Sialkot city. Preference of fish species varies with the change in the level of turbidity in stream water (Ludsin *et al.,* 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 influenced on the distribution of fishes in stream. Stream flow directly affects stream turbidity level, which may restrict fish distribution and movement of fish during breeding season. In present study, generally cyprinids species preferred to live in clear water, whereas, *Channa punctata* and *Heteropneustes fossilis* were found at turbid site with high relative abundance. *Channa punctata* and *Heteropneustes fossilis* which are tolerant species can survive in turbid condition (Ganasan and Hughes, 1998).

The concentration of nitrates in post monsoon and pre monsoon seasons was found correlated with upstream sites of Nullah Aik and Nullah Palkhu. The high concentration of nitrates in upstream sites was mainly contributed by fertilizers used in agricultural land (Rashleigh, 2004). Nitrates make their way into stream through surface runoff after heavy irrigation and rainfalls. Higher concentration of nitrates instream increases the production of native fishes because nitrates increase the production of aquatic plant especially algae (Wolgast and Stout, 1977). However, excessive amount of nitrates in stream may cause eutrophication (Addiscott, 1996).

High concentration of metals recorded in downstream sites have negative impacts on the fish assemblage, whereas, upstream sites with low level of metals represented higher number of fish species. In post monsoon season, stream discharge level becomes high, which dilute the concentration of heavy metals in stream water coming from industrial effluents and municipal sewage. During this season, fishes showed wide distribution in downstream sites especially in Nullah Palkhu, whereas, in pre monsoon season, only four species were recorded in downstream of Nullah Palkhu. Similar results were obtained by Tawari-Fufeyin and Ekaye (2007) in polluted Ikpoba River, Nigeria. This reduction in species richness in downstream sites could be attributed by human activities in the catchment area. Qadir *et al.* (2008) reported that downstream sites of Nullah Aik and Nullah Palkhu are heavily polluted by industrial effluents coming from Sialkot city. These effluents contain many toxic metals such as Pb, Cd and Cr. The sensitive species showed strong negative correlation with heavy metals, if concentration of metals becomes high, fishes migrate to less polluted segment of river or stream (Tawari-Fufeyin and Ekaye, 2007). Svecevièius (1999) showed experimentally that sensitive fishes always avoid living in contaminated waters with heavy metals. However, some tolerant species have developed the tendency to tolerate the heavy metals up to certain limits. The reduction of fishes in downstream is due to increasing industrial and urban pressure (Gafny *et al.*, 2000). Pinto *et al.* (2006) reported significant reduction in species richness and abundance of fishes in downstream of Paraíba do Sul River in Brazil. Pfeiffer *et al.* (1986) studied the loss of fish species and reduction in diversity of Fish species in downstream of Volta Redonda city. Heavy metal pollution in stream has significant negative impacts on structure of fish assemblage in downstream of Nullah Aik and Nullah Palkhu. Similar results were obtained by Snodgrass and Meffe (1998) and Magalhães *et al.* (2002).

Seventeen fish species were recorded from upstream sites, whereas, 11 species were captured from downstream sites of Nullah Aik. Among these species, nine were common to upstream and downstream sites (Figure 5). Seven species were recorded from upstream sites while seventeen species from downstream of Nullah Palkhu, whereas, six species were found in upstream as well as downstream of Nullah Palkhu. High coefficient of community loss was calculated for Nullah Palkhu as compared to Nullah Aik (0.012).

Courtemanch and Davies (1987) and Wright and Welboum (2000) described three possible scenarios (acceptable, criteria needed and unacceptable) of stream conditions on the basis of fish communities in downstream segment. According to criteria developed by Courtemanch and Davies (1987) Nullah Aik is facing partial loss and replacement of fish species at downstream sites. Partial loss of fish species was observed in Nullah Palkhu and downstream showed maximum fish species. The existing situation of fish diversity and water quality in studied streams are highly degraded. Complete loss of fish species has been observed at mid stream sites, which is an alarming situation and unacceptable from ecological point of view. Therefore, this situation needs urgent measure to stop indiscriminate anthropogenic activities in the catchment area to improve water quality and restore the fish communities.

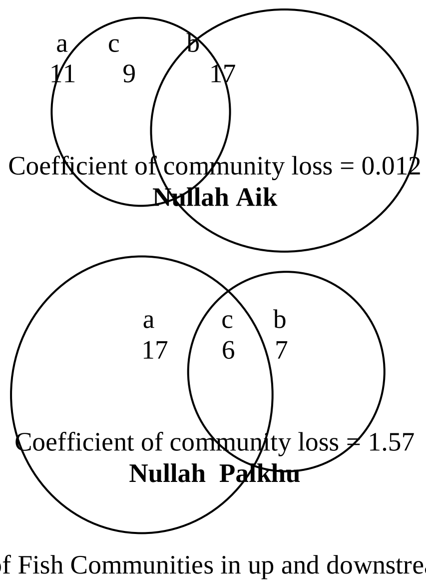


Figure 5 Change in Scenarios of Fish Communities in up and downstream of Nullah Aik and Nullah Palkhu

5. Conclusions

Present study highlighted that stream habitat structure, water quality parameters and metals highly influence the fish assemblage in Nullah Aik and Nullah Palkhu. CCA results indicated strong relationship between species and environmental factors such as stream flow, depth, width, DO, COD, turbidity, NO_3^-, Na, Ca, Fe, Pb, Cr and Cu. Highest fish species richness was recorded in upstream of Nullah Aik and minimum at downstream of Nullah Aik. The fish assemblage was studied in upstream of Nullah Aik was least disturbed where fish assemblage did not showed significant seasonal variations in term of fish diversity. Seasonal variations in fish assemblage were observed at downstream of Nullah Aik and Nullah Palkhu due to anthropogenic activities that change the stream habitat characteristics, degrade water quality and become unfavourable for fishes. Industrial effluents and municipal sewage from Sialkot acts as a barrier between upstream and downstream fish communities and restrict the movement of fishes between stream segments. Present study highlighted the impact of natural as well as human activities on the fish assemblage of Nullah Aik and Nullah Palkhu. The coefficient of fish community loss indicated that there must be management criteria to restore the fish species loss in Nullah Aik and Nullah Palkhu.

Acknowledgements

We thank the Higher Education Commission (HEC), Pakistan, for their financial support during this study period. Thanks are due to Muhammad Hussain (Fisherman), Allah Ditta (Fisherman) and Abdul Rehman for their assistance in the field work.

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(Received for publication 06 February 2009; The date of publication 01 August 2009)