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Benthic Macroinvertabrate distribution in Tajan River Using Canonical Correspondence Analysis

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ABSTRACT

The distribution of macroinvertebrate communities from 5 sampling sites of Tajan River were used to examine the relationship among physiochemical parameters with macroinvertebrate communities and also to assess ecological classification system as a tool for the management and conservation purposes. The amount of variation explained in macroinvertebrate taxa composition is within values reported in similar studies. Results of CCA ordination showed that the dissolved oxygen, water temperature, turbidity, pH and TSS were the most important physicochemical factors to affect distribution of macroinvertebrate communities. The study revealed that macroinvertebrate communities of Tajan River may be explained by physiochemical parameters. Mean values of Shannon–Wiener diversity index calculated for macroinvertebrates ranged from 1.35± 0.07 (S5) to 1.86± 0.10 (S1). According to the Shannon–Wiener diversity index the S1 sampling site was categorized in ''good'' and the sampling sites S2 and S3 in ''moderate'' and S5 in ''moderate to substantially polluted" classes. The anthropogenic disturbances (e.g. trout farms and effluents from factories) impacted abundance and diversity of macroinvertebrate.

Keywords: *Macroinvertebrate, Diversity, Biomonitoring, CCA ordination, Tajan River.*

INTRODUCTION

Tjan River basin is a predominantly calcareous basin draining into the Caspian Sea (Masoudiyan *et al.*, 2010). The present study was conducted to incorporate physicochemical parameters and with macroinvertebrate communities to establish deadline for management of similar streams and rivers in the region. As a rule fluvial ecosystems integrate the biota and biological interactions with all of the interacting physical and chemical processes that collectively determine how systems function (Wetzel, 1983). The macroinvertebrates of streams, including insects, crustaceans, mollusks, and other taxa, are organized into functional feeding groups based on similarities in how food is gathered as well as the food type (Pamplin *et al.*, 2006). Among these organisms' benthic macroinvertebrates, especially insects, are a diverse group and highly adapted to wide range of natural conditions in freshwater environments (Odum, 1983). Aquatic biota in general and insects in particular provide reliable signals of the effects of pollutants or habitat alteration for direct biological assessment and monitoring (Karr and Chu, 1999).

Benthic macroinvertebrates are commonly used for integrated quality assessment of rivers, which have been widely reported and described in the literature (Rosenberg and Resh, 1993; Mandaville, 2002; Ogbeibu and Oribhabor, 2002; Mason and Parr, 2003; Romachandra *et al.*, 2005; Varnosfaderany *et al.*, 2010). They may offer numerous advantages in biomonitoring, which explains their reputation as the most commonly used group in assessing water quality. Macroinvertebrates are considered to be ideal bioindicators due to their: widespread distribution among the river, which allow extensive use of same indicators; species vary in sensitivity to organic pollution; easy sampling with inexpensive equipment (Rosenberg and Resh, 1993). Therefore use of macroinvertebrates in monitoring enables effective spatial analyses to inferences about pollution loads. Today very few rivers are pristine, and most have a long history of alteration. In natural pristine rivers, high diversity and richness of species could be found (Armitage *et al*., 1983). However, high impact due to human activities caused many changes to the communities and biodiversity of the river fauna (Hellawell, 1986; Nedeau *et al*., 2003).

Increasing anthropogenic pressure on lotic systems has captured public interest because of the consequent deterioration of water quality and health problems (Arienzo *et al*., 2001; Bustos- Baez and Frid, 2003; MacNeil *et al*., 2002; Jiongxin, 2004). Nonetheless, the use of benthic macroinvertebrates as bioindicator seems not to be popular or widespread in the Asian ecoregion although this technique provides an inexpensive but good methodology in river classification although the method is widely used in the Northern American and European ecoregions.

Rapid population growth in developing countries places great pressure on the water quality of these nations (Rawlins *et al*., 1998). While the climate and geology of a river catchment mostly determine water quality in the natural environment, human-induced changes to water quality in populated regions over-ride this natural variability (Silva-Benavides, 1996). Human activities such as farming, deforestation, industrial and domestic waste discharges all contribute to deterioration of water quality through changes in runoff characteristics, suspended solids load, and nutrient levels of surface waters. Although mostly under regulatory control in developed countries (Courtemanch et al., 1989), point source discharges of effluents go largely unchecked in developing areas of the world (Payne, 1986). River water quality monitoring programmes which are broadly in place in developed countries are often absent in developing countries (INDRHI, 1999). Thus, in developing countries, where funds available for environmental monitoring may be particularly limited, the relatively low costs of biomonitoring of river quality make this an ideal approach. The aims of this study are (1) to present a comparative account of the physicochemical factors and the species diversity of the benthic macroinvertebrates between polluted and non-polluted sampling sites of Tajan River and (2) to investigate the relationships between physico-chemical factors and macroinvertebrates with the use of CCA analysis.

MARERIALS AND METHODS

Description of the study area

Tjan River basin (2000 km^2) is a predominantly calcareous basin, draining into the Caspian Sea. Geographically the study area lies between 36°09′17″–36°29′49″N lat. and 53°04′57″–53°18′26″E long. The average annual temperature is approx. 15 ^{o}C (Masoudiyan *et al*., 2010). During the period of study water temperature varied between 11 - 23 °C. The region is drained by several rivers including Sefid Rud, Shirin Rud, Garm Rud and Zaram Rud Rivers. For Five sampling sites were selected along the study reach: site (S1) located upstream to the fish farm was considered as a reference station; sites S2 and S3 located downstream to the fish farm outflow and Site 4 was selected below the tributaries of Sefid Rud, Garm Rud and Zaram Rud Rivers and Site was downstream of Tajan River (Fig. 1). The study reach of the River was 50 Km. The stream substrate was mainly stone with cobbles and pebbles in all sampling sites.

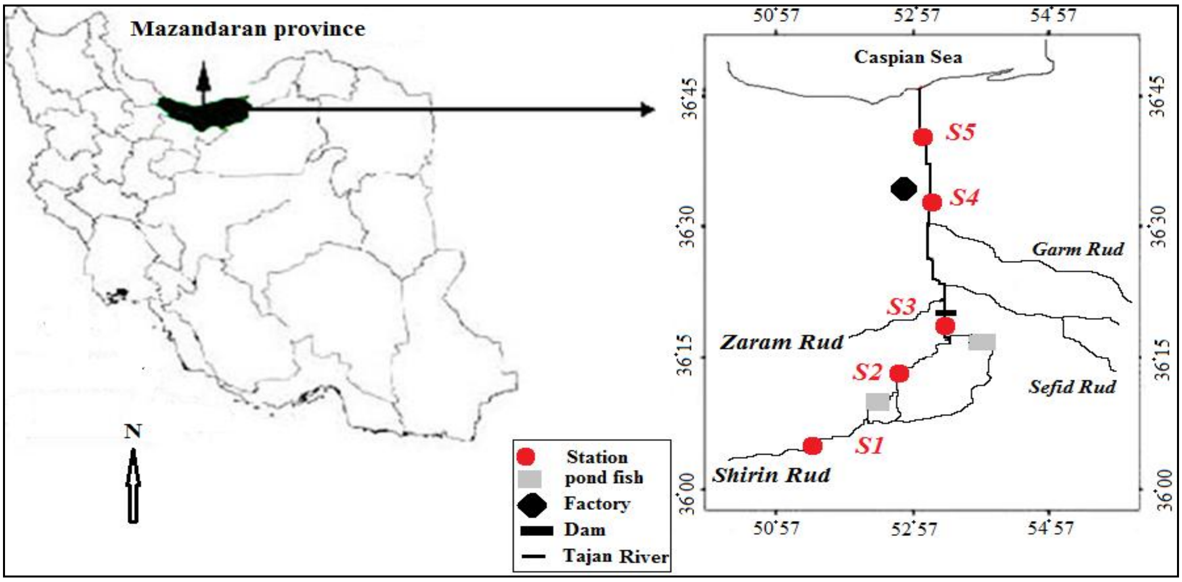

Fig 1. Diagram of study area and sampling stations (S1–S5) (direction of river flow is south to north).

Field sampling and sample analysis

Qualitative samplings of macroinvertebrates were performed seasonally, for one year (2010–2011) in each sampling site. Surber's sampler (40× 40cm aperture, 100-mm-mesh size) was used for benthos sampling by kicking and sweeping in all microhabitats present at the site in accordance with the CEN standard (UNE-EN, 1994). The Surber's sampler contents were checked and emptied out periodically in a plastic jars to avoid losing organisms by accidental overflow from the nets. The samples were preserved in 4% buffered formaldehyde for further identification in the laboratory (Oscoz *et al.*, 2005). Macroinvertebrates were identified to family and genus levels based on recognized keys, including Pescador et al., 2004; Pennak, 1953; Edmonson, 1959; Needham, 1976; Quigley, 1986; Tachet *et al.*, 2000.

Physicochemical measurements were made in each site. Dissolved oxygen, pH, temperature and conductivity were measured in situ by Multiline P_4 and turbidity was measured by Turbidity meter TB-100. TDS was determined with Conductivity TDS Meter and TSS by vacuum pump equipped with cellulose acetate filter, 0.45 micrometer with a sensitivity of 0.001 g (Hughes, 1978).

The biotic indices were used at family level due to the lack of established taxonomic keys for Iranian macrobenthic invertebrates, especially to species level. In this regard, indices at the family level may under or overestimate water quality more than those based on species level. However, the use of indices at the family level may be adequate in terms of cost-efficiency, because they are easy to calculate and require less taxonomic knowledge when taxonomic experts are not available (Rosenberg and Resh, 1993; Varnosfaderany, 2010).

The commonly used non-parametric community structure indices including Simpson's diversity index (D), Shannon – Wiener diversity index (H), McIntosh's index (M) and Jaccard index (J) were calculated, based mostly on the genus (Washington, 1984).

The diversity indices computed include three preferred by Washington (1984) appropriate for use with sample, rather than population, data. These include Simpson's index, D (Simpson, 1949):

$$\text{Simpson's index}\,(D) = \frac{\sum_{i=1}^{S} n_i(n_i-1)}{N(N-1)} \qquad (1)$$

Shannon Wiener diversity index (H$'$) (1964) was calculated using the following formula:

$$\text{Diversity index (H')} = \sum_{i-1}^{s}\left(\frac{n_i}{N}\right)\log_2\left(\frac{n_i}{N}\right) \qquad (2)$$

Where H$'$ is the Shannon–Wiener index of diversity; n_i the total no. of individual of a species and N is the total no. of individuals of all species.

McIntosh's index, M (McIntosh, 1967):

$$\text{McIntosh's index}(M) = \frac{n-\sqrt{\sum_{i=1}^{T} n_i^2}}{n-\sqrt{n}} \qquad (3)$$

The coefficient of similarity (S) was computed following Jaccard (1942):

$$\text{Coefficient of similarity (S)} = \left(\frac{C}{A+B-C}\right) \quad (4)$$

Where C is the no. of common species; A is the total no. of species in community A; and B is the total no. of species in community in B.

Canonical Correspondence Analysis (CCA) ordination

Measurements of benthic and environmental factors were treated as predictors of the macroinvertebrate assemblage during our analyses. We used canonical correspondence analysis (CCA) in PC-ORD (Version 4.17) to determine probable relationships between physico-chemical variables and taxa abundance to differentiate physico-chemical variables which influence structuring of the macroinvertebrate communities (McCune and Mefford, 1999). CCA is a constrained ordination method where axes are created through linear combinations of environmental variables, which makes it a useful method for detecting environmental variables that 'best' describe variation in species data (ter Braak, 1995). CCA is most useful when: (1) species responses are unimodal (hump-shaped), and (2) the important underlying environmental variables have been measured. One should understand that condition 1 causes problems for methods assuming linear response curves (PCA) but causes no problems for CCA, according to ter Braak (1986). Condition 2 results from the environmental matrix being used to constrain the ordination results, unlike any other ordination technique apart from Canonical Correlation. For this reason, CCA has been called a method for "direct gradient analysis" (ter Braak, 1986). Monte – Carlo procedures, using 100 permutations, were used to test the statistical significance of the first three canonical axes. An axis was not interpreted if it was not statistically significant.

All statistical analyses were conducted using the SPSS Version 16.0. Mean values of physicochemical parameters were compared between sampling sites (S1, S2, S3, S4 and S5). One Way analysis of variance (ANOVA) followed by Tukey procedure for post-hoc analyses was conducted to test the significance of differences of biotic indices and physiochemical parameters between sites. The relationship between macroinvertebrate communities and physicochemical variables of sites was conducted by PC-ORD 4.17 software (Bis *et al.*, 2000).

RESULT

Physical and chemical parameters

Mean values (±SD) of water physicochemical parameters in each sampling site, for the whole sampling period, are presented in Table 1. All parameters, except pH, varied significantly at different sampling stations (Table 1). The highest oxygen concentrations DO were observed in S1 and S4 stations and the lowest in downstream site of Tajan River (S5), with significant differences with other sites (F: 16.81; N: 20; $p<0.05$). The EC, Turbidity, TSS and TDS increased gradually from upstream to downstream.

Community structure indices

The McIntosh (M), Shannon–Wiener (H) and Simpson (D) indices showed maximum and minimum values in S1 and S5 stations, respectively. In contrast, the Jaccard index showed the highest and lowest values in S3 and S1 stations. Mean values of these indices showed significant differences between sampling stations ($p< 0.05$), at the period of study (Table 1).

Table 1. Mean values (±standard deviation) of physicochemical parameters and community structure indices at the sampling sites of Tajan River in the period of investigation.

Parameters \ Stations	S1	S2	S3	S4	S5
DO (mg l^{-1})	9.83±0.43^{a}	8.78±0.42^{ab}	8.45±0.68^{ab}	8.93±0.65^{ab}	6.78±0.48^{b}
pH	7.53±0.13	7.78±0.10	7.93±0.48	7.63±0.13	7.88±0.25
EC (µs cm^{-1})	555±36.97^{b}	635±36.97^{b}	815±170.5^{b}	865±79.3^{b}	1560±573.4^{a}
Turbidity (mg l^{-1})	30±4.08^{c}	42±6.68^{bc}	52.50±11.15^{b}	46.75±4.27^{b}	77±9.76^{a}
TSS (mg l^{-1})	88±16.51^{b}	140.25±20.50^{ab}	177.5±50.77^{a}	168.2±14.06^{a}	177.2±27.8^{a}
TDS (mg l^{-1})	316.2±70.4^{c}	423.7±17.9^{c}	790±110.4^{b}	717.5±97.4^{b}	982.5±148.6^{a}
Hardness (mg l^{-1})	142.5± 18.4^{c}	155±12.9^{c}	206±20.3^{b}	241.2±20.1^{b}	280.5±44.5^{a}
Water temperature (^{o}C)	12±1.41^{b}	13.25±1.26^{ab}	15.5±2.38^{ab}	15.88±3.42^{ab}	16.75±4.19^{a}
Water flow (m s^{-1})	0.2±0.08^{b}	0.2±0.08^{b}	2.03±3.32^{b}	14.5±8.19^{a}	14.5±8.19^{a}
Shannon-wiener diversity (H)	1.86±0.10^{a}	1.57±0.12^{ab}	1.39±0.28^{b}	1.65±0.13^{ab}	1.35±0.07^{b}
Simpson's diversity (D)	0.80±0.02^{a}	0.74±0.04^{ab}	0.67±0.13^{b}	0.76±0.03^{ab}	0.67±0.03^{b}
McIntosh Index (M)	0.38±0.03^{a}	0.21±0.04^{bc}	0.18±0.06^{c}	0.27±0.03^{b}	0.15±0.03^{c}
Jacard index (J)	0.38±0.08^{b}	0.58±0.08^{a}	0.65±0.13^{a}	0.51±0.02^{ab}	0.68±0.03^{a}

Values with different letters indicate significant mean differences following Tukey post hoc tests ($p<0.05$).

CCA ordination for relationship between benthic macroinvertebrates and physiochemical parameters in sampling period (2010- 2011)

For all data (2010- 2011), the first three axes generated by CCA explained approximately 41% of the taxa– environment relationship and the axis 1 explained the highest variation with an eigen Value of 21.5% (Table 2). Turbidity parameter showed the highest negative correlation with axis 1. Axis 1 was interpreted as an environmental gradient of decreasing turbidity parameter (Table 2, Fig. 2). Taxa with high positive scores on the first CCA axis included Planariidae (*Phagocata* sp.), Hydrobiidae (*Bithynia* sp.), Chloroperlidae (*Chloroperla* sp.), Perlidae (*Perla* sp.), Heptageniidae (*Epeorus* sp.) and Glossophonidae (*Glossiphonia* sp.), Valvatidae (*Valvata* sp.), Caenidae (*Caenis* sp.) had high negative scores on axis 1 (Fig. 2). Axis 2 explained 12% of the variance in taxa–environment relations (Table 2). Dissolved oxygen negatively correlated while pH, TSS and water temperature positively correlated with axis 2, so this axis was interpreted as a gradient of increasing values of pH, TSS, water temperature and decreasing dissolved oxygen parameter. Taxa with high negative scores on axis 2 included Hydrobiidae (*Potamopyrgus* sp.), Baetidae (*Cloeon* sp.), Ephemerellidae (*Ephemerella* sp.), Hydrometridae (*Hydrometra* sp.), Elmidae, Rhyacophilidae (*Rhyacophila* sp.), Hydroptilidae (*Hydroptila* sp.) and Blephariceridae (*Liponeura* sp.). Few taxa (Naididae, *Simulium* sp. and *Bezzia* sp.) had high positive scores with axis 2 (Fig. 2).

Table 2. Summary of CCA results for the abundance of macroinvertebrate taxa and environmental variables. Axes 1 and 2 were significant following Monte–Carlo permutation procedures ($p<0.05$).

	Axis 1	Axis 2	Axis 3	Total variance
				0.9624
Eigenvalue	0.207	0.115	0.076	
%variance explained in taxa data	21.5	12.0	7.9	
Cumulative %variance explained	21.5	33.4	41.4	
p Value	0.0100	0.0200	0.2300	

Table 3. Intraset correlation coefficients between physico-chemical variables and axes derived from CCA for sampling period

Variable	Axis 1	Axis 2	Axis 3
Dissolved Oxygen	0.409	**-0.511**	0.224
pH	-0.080	**0.550**	-0.148
EC	-0.376	0.143	-0.033
Turbidity	**-0.578**	0.297	0.034
Hardness	-0.277	0.261	0.221
TSS	-0.245	**0.531**	0.339
TDS	-0.432	0.324	0.107
Temperature	0.063	**0.515**	0.068
Flow water	-0.222	-0.196	0.389

Values in bold were considered important in structuring the macroinvertebrate community

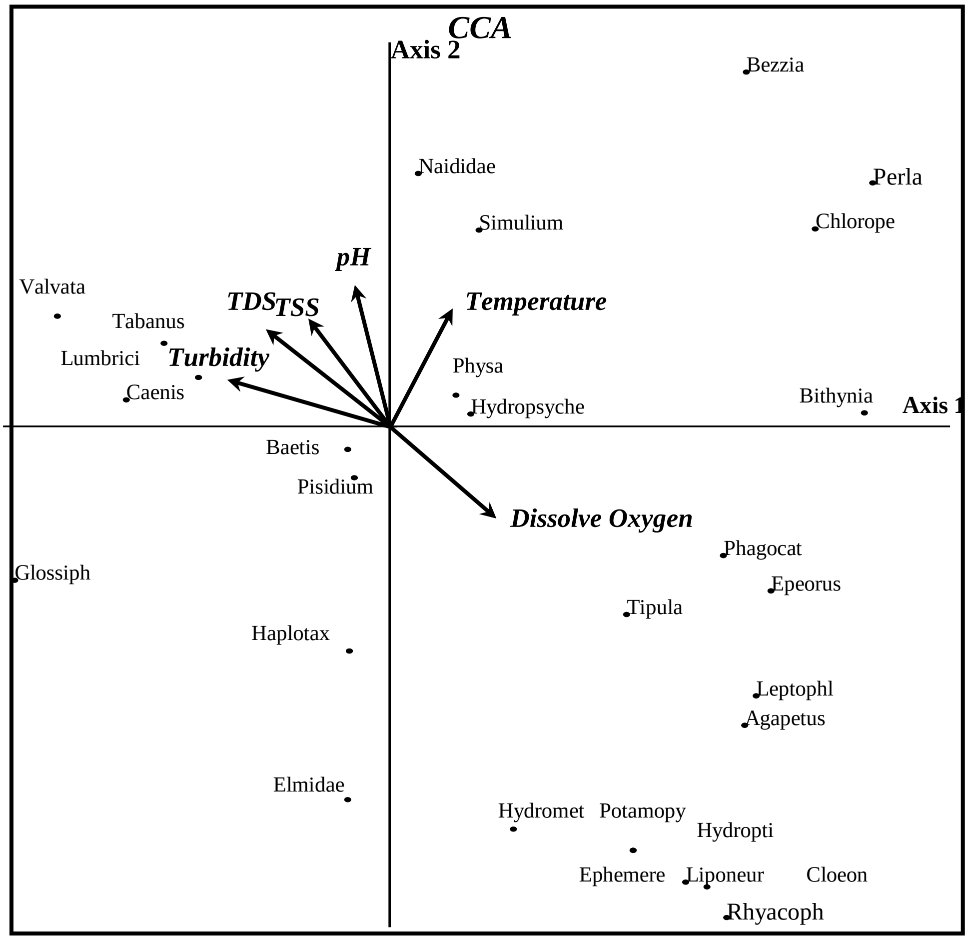

Fig 2. Result of CCA for investigates relationship between macroinvertebrates assemblage and physico-chemical variables in sampling period (2010-2011).

DISCUSSION

Physiochemical characteristics

Components of the mean physicochemical status obtained in this study are associated with variety of contaminating practices, such as outflow of trout farms, domestic effluent discharges, river disturbance and sedimentation, and they are simple summaries for the pollution status of each sampling station. However, caution must be exercised when interpreting these results, since the impacts of pollution and eutrophication on benthic assemblage structure are potentially confounded by an assemblage's dependence on other environmental characteristics, such as riparian forest, periphyton assemblage and sediment characteristics or channel morphology. Values of dissolved oxygen, turbidity, TSS and TDS clearly indicated that trout farm pollution was occurring at S2 and S3 (Table 2). Increases in temperature, suspended solids (i.e., turbidity), organic and inorganic solids and decrease in dissolved oxygen, settlement of suspended solids on the river bottom are physicochemical changes often observed in rivers and streams receiving fish farm effluents (Axler *et al*., 1997; Jones, 1990; Camargo, 1992, 1994; Boaventura *et al*., 1997; Selong and Helfrich, 1998; Bartoli *et* al., 2007; Simoes *et al*., 2008; Ruiz-Zarzuela *et al*., 2009). In this study, these physicochemical alterations were more obvious below the fish farm (S2 and S3) and downstream station (S5), with a clear tendency to be reduced with increasing downstream distance from the fish farm effluent (Table 1). The wastewater treatment system of the fish farm was clearly incapable of preventing marked physicochemical changes in the recipient stream. The fish farm should significantly improve its wastewater treatment system in order to help recover the ecological characteristics of the upper Tajan River. The conductivity increased gradually from upstream to downstream as also mentioned by Boaventura *et al*. (1997). Fish farm effluents did not have a significant impact on the pH of Tajan River though and the slight elevation observed in pH values was not statistically significant and even the pH downstream of the fish farm was still within the acceptable limits of 6.5– 9.5 proposed by various standard schemes (Lawson, 1995; Davis, 1993; Boyd and Gautier, 2000).

The DO concentration reduced as a result of the fish farming activities. The DO concentration was lower below the trout farms throughout the study and the pattern of reduction revealed a monthly cyclic variation as described in Midlen and Redding, 1998 and Lawson, 1995. The lowest value of DO (6.78± 0.48 mg/L) was observed in S5 and sampling sites below the fish farm (S2 and S3). Furthermore; the lowest value of DO observed in Tajan River still exceeded the upper limit of DO concentration (5 mg l^{-1} or more for DO) that is recommended by the Global Aquaculture Alliance (Boyd and Gautier, 2000).

Diversity indices

Community structure index is a synthetic measurement for biological structure which incorporates two distinct aspects e.g. the number of taxa (richness) and the distribution of individuals among taxa (evenness). Diversity indices depend on the quality and availability of habitats (Barbour et al., 1999); they reflect the impact of all investigated stressors independent of ecoregion boundaries. According to the result the highest McIntosh (M), Shannon –Wiener and (H) Simpson (D) values were observed in sampling site S1 which may be due to presence of rich and undisturbed habitat structure in place, while the lowest values were observed in downstream station (S5). Low values of these indices are indicators of pollution or disturbances in environmental conditions of the River. Wilhm and Dorris (1968) set diversity index <1 for highly polluted, 1– 3 for moderately polluted and > 4 for unpolluted water bodies. In this study, the Shannon–Wiener diversity index ranged from 1.35± 0.07 (S5) to 1.86± 0.10 (S1). According to the Shannon–Wiener diversity index, the S1 station was categorized in ''good'', stations S2 and S3 ''moderate'' and S5 ''moderate to substantially polluted'' classes (Table 1). Other biological indices followed the similar trend and indicated an overall increase in nutrient pollution, particularly along the downstream reach of the river. In contrast, the Jaccard index showed highest and lowest values in S3 and S1 sampling sites respectively (Table 1). Mean values of these indices revealed significant differences between sampling stations ($p < 0.05$) (Table 1). Based on Jaccard index the highest similarity was observed between the most polluted stations since only few organisms tolerate the pollution and these organisms mainly were similar in different reaches of the river (Kamali *et al*., 2009).

Relationship between macroinvertebrates assemblage and physico- chemical parameters

The main purpose of the present study was to investigate the relationship between benthic macroinvertebrates and physiochemical parameters and determine distribution patterns of the benthic macroinvertebrate communities in the Tajan River. Surveys of this kind have been criticised for their inability to detect or interpret subtle environmental changes leading to changes in community composition and therefore to differentiate between natural changes and those caused by pollution (Mason, 1996). Since, detailed site specific information is not usually available in developing countries; therefore, baseline surveys of the kind conducted in this study are necessary to produce a general view of the biological communities present within a particular area. Using a study plan involving gradient of increasing stress enabled us to quantify and rank the influence of environmental factors on macroinvertebrate assemblages. The differences observed in macroinvertebrate assemblage structure and abundance reflected the differences in location of site (upstream or downstream) and distance from sources of human activities and resulting impacts (e. g. aquaculture and industrial effluents *etc*.). CCA (Table 3) analysis showed that variation in macroinvertebrate assemblages was related to turbidity, dissolved oxygen (DO), pH, TSS, TDS (based on graph) and water temperature. A significant positive relationship was observed between temperature and abundance of macro invertebrate assemblages. Temperature plays an important role in determining respiration rates of benthic macroinvertebrates and thereby influencing oxygen availability (Hauer, 1996). Pronounced temperature differences were observed between upstream (S1) and downstream (S5) sites and water temperature increased along the gradient of river towards downstream. Our study showed a strong influence of pH on the macroinvertebrate community. Similar results were reported from northern and southern Finland and eastern Russia (Paavola et al., 2000, Soininen and Könönen 2004; Schletterer et al., 2011). Several excellent field studies dealing with the effects of acid waters on stream biota have been published (Pennsylvania department of health, 1967; Dinsmore, 1968; Parsons, 1968) which are useful for comparison of effects of pH on macroinvertebrates in laboratory studies and in the field. These studies describe in details the chemical and biological conditions over a 4- 27 month period. Mayfly *Ephemerella* sp. was not collected from waters with a pH lower than 5.5 (Dinsmore, 1968).

Based on CCA analysis, turbidity showed negative correlation with axis 1 which is interpreted as gradient of decreasing turbidity (Fig. 2). Several taxa of macroinvertebrates e. g. Glossophonidae (*Glossiphonia* sp.), Valvatidae (*Valvata* sp.) and Caenidae (*Caenis* sp.) positively correlated with this parameter and therefore proposed as taxa tolerant to turbidity. On the contrary, Planariidae (*Phagocata* sp.), Hydrobiidae (*Bithynia* sp.), Chloroperlidae (*Chloroperla* sp.), Perlidae (*Perla* sp.) and Heptageniidae (*Epeorus* sp.) decreased with increasing turbidity. There have, however, been a number of review studies documenting the effects of increased turbidity in streams on macroinvertebrates (e.g., Lloyd *et al*., 1987; Newcombe, and MacDonald, 1991; Ryan, 1991; Waters, 1995; Wood and Armitage, 1997; Death, 2000). In general, these reviews concluded that high turbidity can reduce invertebrate abundance and diversity by: smothering and abrading, reducing their periphyton food supply or quality and reducing available interstitial habitat. Moreover, high turbidity also often results in sediment deposition, altering substrate composition and changing substrate suitability for some taxa (Wood and Armitage, 1997). Sediment deposition creates conditions that are generally unsuitable for most aquatic insects (Jowett *et al*., 1991; Death 2000; Harding *et al*., 2000). However, as little is known about the effects of high turbidity on common invertebrates, little guidance can be given as to what an acceptable upper level of turbidity is to minimise loss of sensitive taxa.

According to result of CCA (Figure 2), taxa on axis 2 included Hydrobiidae (*Potamopyrgus* sp.), Baetidae (*Cloeon* sp.), Ephemerellidae (*Ephemerella* sp.), Hydrometridae (*Hydrometra* sp.), Elmidae, Rhyacophilidae (*Rhyacophila* sp.), Hydroptilidae (*Hydroptila* sp.) and Blephariceridae (*Liponeura* sp.) showed a positive correlation with increasing dissolved oxygen and decreasing pH, temperature and TSS, thus these benthic macroinvertebrates limited to clean and oxygenated water and are sensitive to polluted water with high pH, total suspended solids (TSS), water temperature and may be proposed as sensitive taxa for bioassessment of water quality. In contrast, few taxa (Naididae, *Simulium* sp. and *Bezzia* sp.) showed high positive scores on axis 2 and a negative correlation with increasing dissolved oxygen and decreasing pH, temperature, TDS and TSS. 21.5% of variance explained by axis 1 where turbidity parameter had the negative correlation with this axis. Glossophonidae (*Glossiphonia* sp.), Valvatidae (*Valvata* sp.), Caenidae (*Caenis* sp.) showed positive correlation with increasing turbidity, in contrast, abundance of Planariidae (*Phagocata* sp.), Hydrobiidae (*Bithynia* sp.), Chloroperlidae (*Chloroperla* sp.), Perlidae (*Perla* sp.), Heptageniidae (*Epeorus* sp.) decreased with rises in turbidity values (Fig. 2; Table 3). Our results show that macroinvertebrate communities can be explained by the physiochemical variables in Tajan River. Many interacting environmental variables influenced spatial distribution of macroinvertebrates in this study. Owing to relatively lengthy study reach (50 Km) of Tajan River great amount of Variance explained were observed on the first three axes (41%). Results from studies that have used CCA to relate macroinvertebrate communities to physiochemical parameters have reported greater amounts of variation explained (40–60%) in macroinvertebrate communities by environmental parameters as these studies also were conducted on a similarly large scales (i.e., stream reaches, watersheds) (Richards *et al.*, 1993; Griffith *et al.*, 2001; Riva-Murray *et al.*, 2002). Based on our results CCA is a very useful examining tool, since it is able to extract all variables important in structuring macroinvertebrate data sets and relates physiochemical variables to changes in taxa composition (taxa counts) at the same time.

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پراکنش بی مهرگان بزرگ رودخانه تجن با استفاده از آنالیز تحلیلی کانونی

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چکیده

پراکنش جوامع بی مهرگان بزرگ ۵ ایستگاه نموه برداری از رودخانه تجن برای درک ارتباط بین پارامتر های فیزیکی با جوامع بی مهر گان بزرگ آبزی و نیز ارزیابی سیستم طبقه بندی اکولوژیکی به عنوان ابزاری برای مقاصد مدیریتی و حفاظتی مورد بررسی قرار گرفت. میزان تغییرات مشاهده شده دربین طبقات بی مهرگان بزرگ ابزی درمحدوده مقادیرگزارش شده در بررسی های مشابه بود. نتایج حاصل از آنالیز مولفه های CCA نشان داد اکسیژن محلول، درجه حرارت، کدورت، pH، و کل مواد معلق (TSS) مهمترین فاکتور های فیزیکو- شیمیایی موثر بر روی پراکنش جوامع بی مهرگان بزرگ آبزی بودند. این بررسی نشان داد که جوامع بی مهرگان بزرگ ابزی رودخانه تجن را می توان با استفاده از پارامتر های فیزیکو شیمیایی توصیف کرد. متوسط شاخص تنوع شانون- واینر محاسبه شده برای این ارگانیزم ها در دامنه ۱/۳۵±۰/۰۷ (ایستگاه ۵) تا ۱/۸۶±۰/۱۰ (ایستگاه ۱) قرار داشت. بر اساس شاخص تنوع شانون – واینر ایستگاه ۱ در طبقه بندی "خوب" و ایستگاه نمونه برداری ۲ و ۳ در طبقه "متوسط " و ایستگاه ۵ طبقه "متوسط تا زیاد" از نظر آلودگی قرار گرفتند. مقادیر متوسط شاخص شانون- واینر محاسبه شده بیانگر تاثیر اثرات آشفتگی های ناشی از فعالیت انسانی (برای مثال مزرعه پرورش قزل آلا و فاضلاب کارخانه ها) روی فراوانی و تنوع بی مهرگان بزرگ آبزی بود.

*مولف مسئول