Bioassessment of Kordan Stream (Iran) Water Quality Using Macro-Zoobenthos Indices

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Abstract

Changes in water and habitat quality of Kordan Stream were examined using community structure and biotic indices at 3 sites during 2008-2009. This investigation resulted in inventories of benthic insect communities being obtained from this stream. It also resulted in two metrics being calculated from benthic insect communities. Of the metrics used, one indicated EPT taxa richness and one involved a biotic index, HFBI, for organic pollution. Water temperature, water velocity, water depth, dissolved oxygen, BOD5, pH, specific conductivity; phosphate and nitrate concentrations were within ranges usually capable of supporting a diverse biota. Samples were dominated by insects and yielded 142 macroinvertebrate taxa. The scores calculated for HFBI was lowest (4.67) and rated good water quality (some organic pollution probable) at site 1 and increased to 5.45 rated fair (fairly substantial pollution likely) at site 3. EPT ratings were "under a little perturbation" at three sites, suggesting high taxa richness and habitat quality in Kordan Stream.

Keywords: Kordan Stream, Macrobenthose, Water quality, HFBI, EPT richness

1. Introduction

Running waters are amongst the most threatened ecosystems in the world (Allan and Flecker, 1993). Streams are usually highly variable environments that harbor diverse and unique biota (Malmqvist and Hoffsten, 2000). Anthropogenic activities have strong effects on aquatic ecosystems leading to widespread modification of the physical habitat and consequently of biotic communities and ecological functioning (Principle, 2007). Therefore, river or stream restoration requires an understanding of the structure and function of stream corridor ecosystems and the physical, chemical and biological processes that shape them (USDA, 2000; Hu, 2006).

To assess the quality of running waters, chemical analyses alone are inadequate (Karr and Chu, 1999). In many regions aquatic resources have been degraded because of non point source pollution and alterations of stream channels, riparian areas and entire stream catchments (Fore *et al*., 1996; Griffith, 2002). Furthermore biological monitoring using macroinvertebrates assemblage can give an indication of past as well as present conditions (Fenoglio, 2002). In addition, biological monitoring is valuable for determining natural and anthropogenic influences on river resources because biota integratively respond to stress from multiple spatial or time scales and several pathways including habitat and water chemistry (Karr, 1981; Ohio EPA, 1987; Rosenberg & Resh, 1993; Weigel and Robertson, 2007).

Macroinvertebrate responses (e.g., absence or presence, number of individuals, deformities, etc.) reflect short and long term environmental conditions within their native watershed (Suozzo 2006), and reflect intermittent discharges and the synergistic effects of in-stream chemical contaminants often too dilute to detect (Bode *et al.* 1991; Suozzo, 2006). Recently many techniques, protocols, and indices have been developed to monitor stream quality using changes in taxa composition, diversity and functional organization of aquatic insects (Hilsenhoff,

1988; Plafkin *et al*. 1989; Shieh, 2000). Such Rapid Bioassessment Protocols (RBPS) developed by Barbour *et al*. (U.S. EPA 1999), have greatly increased the assessment efficiency and effectiveness of these surveys. RBPS can reflect overall ecological integrity and directly assess the status of a water body (Hu, 2006).

The objectives of this study were to collect synoptic water quality information (i.e., temperature, dissolved oxygen, pH, conductivity, turbidity, and discharge), to determine the taxonomic composition and relative abundance of macroinvertebrate community, water quality assessment using HFBI and finally using overall macrobenthose diversity and EPT taxa richness to evaluate the stream health.

1.1. Study area

Kordan stream is located in north of Karaj city, 40 km west of Tehran ($50^{\circ}50'$ to $50^{\circ}55N$, $35^{\circ}55'$ to $36^{\circ}05'$ E) with an elevation of 1408m in Alborz mountains ecoregion. The stream is about 75 km long and has a drainage area of 1100 km^2 (Figure 1).

The stream basin has annual precipitation of about 650 mm with the highest precipitation in April and the lowest in September. Local air temperatures historically vary between -6 and 29 ^{0}C. Climatic condition is moderate with cold winters and without severe drought in the summers. A part of the river basin has been developed for agricultural purposes and rainbow trout culture. Water from the stream is diverted for irrigation throughout the summer. Furthermore, this area is profitable for producing fruits, nuts (e.g., walnut) and fish, but is a recreational area as well. During the summer, the water quality of river is adversely affected due to release of effluent and garbage from human settlement and also the increase in tourism activities.

2. Materials and Methods

An annual study of macroinvertebrates in Kordan stream was conducted for the first time. A surber sampler (area = 30×30 cm^2, mesh size = 250 µm) was used to collect 3 samples of benthic aquatic insects at each sampling site monthly from February 2008 to January 2009 (Figure 1). Three replicates were taken from different subsites, two near the banks and one in the centre to cover all different microhabitats (pools and riffles).

Qualitative collections were also made by examining rocks, wood debris, leaf debris, and other microhabitats by hand at each sampling site. All invertebrate collections were preserved in 4% formaldehyde in the field and then taken to the laboratory for further sorting, identification, and enumeration.

Aquatic insects were identified to family level (and genus when possible), except nymphs of chironomids, which were identified to tribe or subfamily. Specimens were identified to family or genus level mainly according to the Aquatic Entomology (McCafferty, 1981) and Aquatic insects of North Europe (Nelson, 1997).

Physicochemical conditions prevailing at each station were also measured during each collection period. These parameters included water temperature, dissolved oxygen concentration and biochemical oxygen demand (Winkler method), pH (Aqua Merck. D6100, pH meter), and specific conductance (HORIBA E5-14E conductivity meter). Stream velocity was determined using a Sensa Z300 OTT, and stream depth was recorded using a secchi tube depth. Measures for nitrate and phosphate were determined for the water samples from each site, using the procedures by Greenberg *et al*. (1992).

Effects of all environmental variables on macroinvertebrate abundances were evaluated using correlation and differences in the number of individuals, number of taxa and biotic indices scores between the sites were analyzed using One-Way ANOVA. Water quality was analyzed using Family level Biotic Index Score System developed by Hilsenhoff (1988) and EPT Taxa Richness (Ephemeroptera, Plecoptera and Trichoptera) was based on Davis and Simon (1995).

3. Result

3.1 Physico – Chemical Characteristics of the area

Ranges of the physicochemical and hydrological parameters in Kordan Stream are listed in Table 1 and 2. Mean water velocity was 116 $cm.s^{-1}$ in Kordan stream with a minimum of 110 $cm.s^{-1}$ in August and a maximum of 126 $cm.s^{-1}$ in April. Water depth rarely exceeded 75 cm.

The minimum and maximum water temperature recorded was 4ºC during January and 18.7ºC during July respectively, with an average of 11.52 ºC. Minimum dissolved oxygen concentration, 9.3 $mg.l^{-1}$, was recorded during July and maximum dissolved oxygen concentration, 11.9 $mg.l^{-1}$ occurred during January. Dissolved oxygen values were above saturation and BOD_5 was low at all times at all sites. The differences in dissolved oxygen concentrations and BOD_5 between the stations were not significant ($p > 0.05$).

The EC values were between 256 and 417 μs/cm with a maximum in the low-water period and minimum in the high-water period. EC values increased from 313 $\mu s.cm^{-1}$ at site 1 (Aghasht) to 347 $\mu s.cm^{-1}$ at site 3 (downstream) due to the effect of waste water discharge from villages and polluted water from agricultural areas.

The amount of NO_3-N ranged from 0.26 $mg.l^{-1}$ to 0.56 $mg.l^{-1}$and PO_4-P ranged from 0.011 $mg.l^{-1}$ to 0.027 $mg.l^{-1}$ during the study period. The PO_4-P values were generally low at all sites. NO_3-N and PO_4-P concentrations increased from upstream sites toward downstream. The use of agricultural fertilizers and urban sewage are believed to increase the Nitrate Nitrogen.

3.2 Macroinvertebrate community

A total of 34500 individuals representing 142 taxa, 4 phyla, 9 classes, 21 orders, 56 families, 11 subfamilies, 1 tribe, and 38 genera were identified throughout the year and during this study (Table 3).

In terms of both number of individuals, and number of taxa, 10 orders, 42 families, insects were dominant. Dipterans with 13 families, 7 subfamilies, 1 tribe, 9 genus, coleopteran insects with 7 families, 5 genus, and Plecoptera, Ephemeroptera, Trichoptera each one with 5 families, were present at all stations during most collections. During the study period, richness was lowest in May 2007 with 25 taxa and the highest in March and October 2007 with 104 taxa. From a total of 142 taxa, 121 (8 classes, 20 orders, 48 families, 10 subfamilies, 1 tribe, 34 genus) were found in site 1 (Aghasht, one of the upstream tributaries), 112 (6 classes, 16 orders, 44 families, 11 subfamilies, 1 tribe, 34 genus) in site 2 (Baraghan, upstream of Kordan stream), and 111 (7 classes, 18 orders, 44 families, 10 subfamilies, 1 tribe, 31 genus) in site 3 (downstream of Kordan). Therefore, richness was greatest at site 2, and lowest at site 3. The most ubiquitous taxa included Ephemeroptera (*Epeorus, Rhithrogena, Baetis* and *Cloeon*) Plecoptera (*Chloroperla*), Trichoptera (Hydropsychidae), and Diptera (Athericidae, Simuliidae, Tabanidae). Density was also highest at site 2 with 3216 $ind.m^{-2}$, and lowest at site 3 with 2050 $ind.m^{-2}$ (Table 3).

The scores calculated for Family – level Biotic Index (FBI) were lowest (4.67) and rated good water quality at site 1 (some organic pollution probable). The scores at sites 2 and 3 were 5.04 and 5.24 and rated fair (fairly substantial pollution likely) (Table 4).

The value calculated for EPT Richness at site 1 was 8, "under a little perturbation", for sites 2 and 3 were 9 and 7 respectively, also "under a little perturbation". However, the number of families in orders Ephemeroptera, Plecoptera, and Trichoptera (EPT Richness) was not significantly different among sites during the study.

4. Discussion

A timely review of empirical studies, conducted on the biodiversity of stream insects, was published by Vinson and Hawkins (1998). In the summary of this review, it was generally found that physical complexity promoted biological richness. Kordan Stream with stony bedrock, low stream order and high elevation is located in the temperate zone and a mountainous region. The mean annual temperature shows that this is a region with cold winters and mild summers. This has favored a suitable condition for the macro invertebrates.

According to nutrients measured during this study, Kordan stream is classified as oligo-mesotrophic stream (Smith *et al*., 2006). Although the water quality of the downstream site was lower than that of upstream sites, but the pollution level as a whole was not considerable and this stream could be regarded as a rather clean and healthy environment.

4.1 Macroinvertebrate communities

A total of 142 macroinvertebrate taxa distributed across 1 superphylum, 4 phyla, 3 subphyla, 9 classes (Insecta, Oligochaeta, Arachnida, Gastropoda, and Crustacea, Pelecypoda, Collembola and Hirudinea), 21 orders, 56 families, 11 subfamilies, 1 tribe and 38 genera were collected from the sampled sites during the time of study. Samples were dominated by insects and yielded 10 order, 42 families and 11 subfamilies with a density of 34500 $ind.m^{-2}$. Dipterans with 13 families, Coleopterian with 7 families and Ephemeroptera, Plecoptera and Trichoptera every one with 5 families were composed the most richness. It seems that differential abundance and high richness in Kordan stream is due to naturally-occurring variations in hydrological and ecological properties such as low stream order (Crunkilton and Duchrow, 1991; Grubaugh *et al*., 1996), proper velocity (in the range of 30 to 120 $cm.s^{-1}$) (Beauger *et al*., 2006) and flow condition (Nelson and Lieberman, 2002; Wood *et al*., 2005).

During the study period, the lowest values of richness were observed in May, high-water period, and the highest was observed in March and October, low water period. During low water period, the habitats are more stable and time for macroinvertebrate colonization is longer allowing the increment of the species richness and abundance (Principle *et al*., 2007). Moreover, in Kordan Stream, insect abundance patterns were seasonal and the difference

in the number of individuals between the months was significant ($p < 0.05$). For example, emergence of mayflies (Ephemeroptera, Baetidae) was observed during winter or some dragonflies and damselflies had explosive emergence during April and May, and then soon disappeared. In general, flood regime would influence the temporal patterns of macroinvertebrate communities by decreasing total number of invertebrates (Merritt and Cummins, 1996; Gonzalez *et al*., 2003; Baraille *et al*., 2005), or exerts a great influence on the stream-dwelling invertebrate communities (Baptista *et al*. 2001).

Regarding the number of taxa collected over the annual period and from two upstream sites 1 and 2, site 2 with 121 taxa showed the highest number. Density was also highest at site 2 with 3216 ind.m^{-2}, and lowest at site 3 with 2050 ind.m^{-2} .This may be due to the presence of larger amounts of microhabitat in confined area and more stable condition at this sampling site (Bass, 1995; Nelson and Lieberman, 2002). Trichopteran insects were the most frequent order at site 2 because of appropriate substrates (rocky substrate, large amount of woody debris) for development of periphyton (and aufwuchs) in this site. Plecoptera, Coleoptera and Diptera were also abundant in this site for adequate sources of coarse particulate organic matter (tall trees in riparian zone) (Rohasliney and Jackson, 2007). Also large woody debris entrap the allochthonous organic material and forming leaf packs as attachment sites for most benthic macroinvertebrate colonization (Vanderwel *et al.,* 2006).

Site 1 and 3 were more similar, just at site 3, dominance of gatherers (mainly chironomids) and high frequency of Oligochaeta, Arachnida and Gastropoda may be interpreted as a cumulative rural sewage and runoff agricultural activities (Cao *et al.*, 1997). However, It was found that there were not significant differences in the number of taxa and number of individuals between upstream sites and downstream (One-way ANOVA, $p>0.05$).

During the study period, Family-level biotic index score for site 1 was 4.67 which indicate "Good" water quality with some organic pollution probable. The scores calculated for sites 2 and 3 were 5.04 and 5.45 rated “Fair” with "fairly substantial pollution likely "(Hilsenhoff, 1988). Furthermore, during the study period, clear differences in FBI scores were not observed among stations ($p>0.05$).

EPT Richness value at site one was 8, “under a little perturbation”. Sites 2 and 3 were also “under a little perturbation” with scores 9 and 7, respectively (Bode, 1993). The number of families in orders Ephemeroptera, Plecoptera, and Trichoptera (EPT Richness) was not significantly different among sites during the study period. However, in Kordan Stream, species richness was generally high, insects were much more prevalent than Oligochaetes and pollution-intolerant taxa were present throughout the study period at all sites, indicating high water and habitat quality.

Evidence generated by this study indicates that anthropogenic activities has not resulted in negative impacts to benthic macroinvertebrate assemblages in the Kordan stream and this stream be considered to be in good condition environmentally in all stations (from a water quality perspective according to HFBI values) as well as in terms of their stream biota (i.e., benthic macroinvertebrate assemblage composition and EPT richness), and the environmental conditions and habitat specifications play a major rule in the high richness and distribution of these organisms. Although at present biological integrity of this stream in terms of species richness (and productivity) is relatively intact and it is in generally in good condition, downstream part of it is going to be influenced by non point perturbations such as stressful condition, habitat degradation, deforestation and construction. Finally, based on its faunal assemblages, if this stream is protected from pollution and other ecological risk factors then it could serve as an ecological diversity unit in the area and serve as a good baseline for future comparisons. This situation emphasizes the importance of formulating and implementing a management program regarding the control of human activities development in the future, of course within a framework of an integrated management plan for the whole of its sub-river basin.

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Table 1. Physico-chemical data in Kordan stream, February 2008- January 2009

	February	March	April	May	June	July	August	September	October	November	December	January
TEMP(°C)	6.86	12	12.6	14.0	17.7	18.7	15.6	15.3	11.56	5.6	4.33	4
EC ($\mu s.cm^{-1}$)	323	396	263	256	327	324	417	401	391	354	366	350
DO($mg.l^{-1}$)	11.9	10.9	10.7	10.1	9.44	9.3	10	10	11.5	11.7	11.8	11.9
BOD_5 ($mg.l^{-1}$)	1.69	1.72	1.43	1.27	2	2.17	2.9	2.42	2.11	2.03	1.53	1.05
pH	8	8	8	8	8	8	8	8	8	7.5	7.5	7.5
NO_3-N ($mg.l^{-1}$)	25	27	18	17	13	12	11	11	15	18	19	21
NO_3-N ($mg.l^{-1}$)	0.6	0.56	0.37	0.42	0.56	0.26	0.28	0.31	0.45	0.56	0.52	0.56

Table 2. Physico-chemical data from Kordan stream, St=Station

	St1	St2	St3
TEMP(°C)	11.53±4.48	11.63±4.96	11.7±5.65
EC(µs.cm^{-1})	313±76.02	343±49.35	347±44.04
DO(mg.l^{-1})	11±0.87	10.86±0.77	10.58±0.62
BOD_5(mg.l^{-1})	1.12±0.49	1.56±0.38	2.1±0.71
pH	7.8±0.31	7.8±0.31	7.8±0.31
PO_4 (mg.l^{-1})	0.016±0.002	0.016±0.004	0.018±0.005
NO_3 (mg.l^{-1})	0.47±0.15	0.45±0.16	0.51±0.21

Table 3. Taxonomic composition and abundances of macroinvertebrates collected from all sites in Kordan Stream, February 2008- January 2009.

Family	Subfamily	Genus	St1	St2	St3
Baetidae		Baetis	644	655	522
		Cloeon	489	689	78
Heptageniidae		Epeorus	33	100	78
		Rhithrogena	11	-	11
Caeniidae		Caenis	-	11	-
Leptophlebiidae		Paraleptophlebia	11	11	11
Oligoneuriidae			33	56	11
Capniidae		Capnia	22	22	22
Chloroperlidae		Chloroperla	22	22	22
Perlodidae	Isoperlinae	Isoperla	11	11	-
		Isogenoides	178	644	33
Perlidae	Acroneuriinae		11	55	11
	Perlinae		11	33	67
Leuctridae		Leuctra	22	278	11
Hydropsychidae			11	-	-
Brachycentridae		Oligoplectrum	11	11	11
		Micrasema	11	11	11
Hydroptilidae		Ochrotrichia	11	22	11
Glossosomatidae	Glossosomatinae		56	11	11
Polycentropodidae			11	0	--
Coenagrionidae		Argia	11	11	11
Aeshnidae		Aeshna	11	11	11
Athericidae		Atherix	11	22	11
Blephariceridae		Bibiocephala	56	11	11
Chironomidae			410	710	810
	Diamesinae*		11	11	11
	Orthocladinae*		22	22	33
	Chironominae*	<Tanytarsini>	22	22	33
	Tanypodinae*		11	11	11
	Telmatogetoninae*		11	11	-
Simuliidae	Simuliinae		267	189	44
Psychodidae		Telmatoscopus	11	11	11
Empididae		Chelifera	11	11	11
		Hemerodromia	11	11	11
Dixidae		Dixa	11	11	11
Stratiomyidae		Euparyphus	11	11	11
Tabanidae			11	11	11
Tipulidae		Tipula	11	11	11
	Limoniinae	Antocha	11	-	-
Culicidae			11	11	11
Ceratopogonidae			-	11	11

Dolichopodidae			-	-	11
Elmidae		Elmis	33	22	11
		Phanocerus	22	11	11
Gyrinidae		Dineutus	11	22	11
Helodidae		Scirtes	11	11	-
Hydrophilidae		Laccobius	11	11	11
Hydroscaphidae			-	11	-
Hydraenidae		Hydraena	11	-	-
Curculionidae			11	-	-
Hebridae			-	11	11
Aphididae			11	11	-
Pyralidae			11	11	11
Braconidae			11	11	-
Sisyridae			-	11	-
Isotomidae		Isotomurus	11	11	11
Gammaridae		Gammarus	11	11	11
Physidae		Physa	-	11	11
Limaeidae		Limaea	11	-	-
Valvatidae		Valvata	11	11	11
Hydrobiidae		Potamopyrgus	-	11	11
Sphaeridae		Pisidium	-	11	-
Lumbricidae			11	11	22
Lumbriculidae			-	11	11
Glossiphonidae			-	-	11
Planariidae			-	11	11
Pisauridae			11	11	11
Thomisidae			11	11	11
Hygrobatoidea			11	11	22
ind.m^{-2}			2416	3216	2061

(* identified from nymph, <>: tribe)

Table 4. HFBI and EPT Richness values at different sites in Kordan stream, February 2008- January 2009.

		Feb	Mar	April	May	June	July	Aug	Sep	Oct.	Nov	Dec	Jan	Ave
HFBI	St1	5.43	5.36	4.92	4.67	5.47	5.39	5.3	4.83	3.9	3.82	2.23	4.98	4.67
	St2	5.86	5.67	5.58	4.94	5.43	5.53	5.58	4.94	4.55	4.43	2.89	5.15	5.04
	St3	5.9	5.72	5.61	5.36	5.48	5.67	5.72	5.23	5.11	4.65	3.19	5.28	5.24
EPT Richness	St1	4	7	5	5	6	7	7	9	10	11	8	13	8
	St2	9	8	5	4	8	9	6	10	12	10	11	10	9
	St3	6	7	5	3	5	5	7	7	9	9	8	10	7

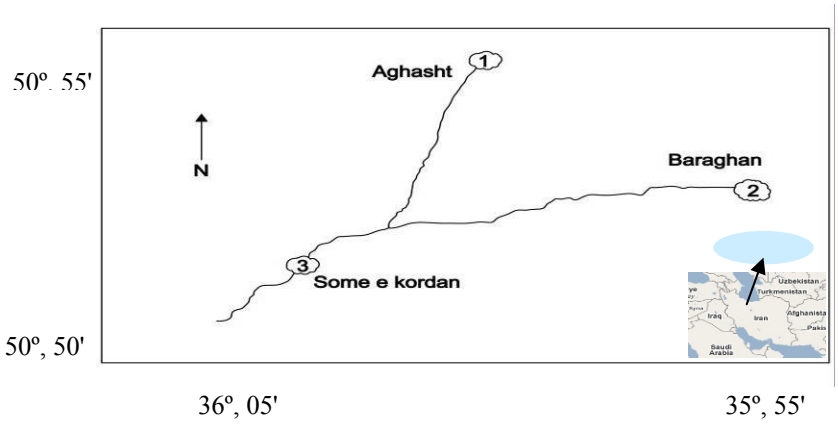

Figure 1. Schematic map of Kordan Stream and location of stations (not to scale).