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Environmental Assessment of Downstream Water from Latian Dam Using Benthics as a Biological Index

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***Abstract*—T**his paper reports the results of a study on the environmental assessment of the downstream water using benthics as a biological index of water quality in Jajrood River. The research was carried out at four sampling sites of a downstream section of Latian Dam in the fall-winter and spring seasons. Using the Hilsenhoff Biotic Index to assess water quality at the sampling sites.the monthly and seasonal flow water changes were investigated in the Jajrood catchment for a period of 30 years. Statistical investigations indicate that spring is the wettest season in the Jajrood catchment , and the result of a paired t-test indicates that the seasonal differences of all benthic families except Rhyacophilidae is significant. According to the Hilsenhoff Biotic Index results, the water quality downstream of Latian Dam was average at three sampling sites, and the water quality was only good at site 2.The dominant benthic families were Chironomidae and Caenidae. In this study, the presence of pollution-tolerant families in the sampling sites indicates that these sites are ecologically unhealthy and that the flow water at the downstream section of Latian Dam differs considerably from the environmental flow water requirements of aquatic ecosystems during the fall-winter and spring seasons.

***Keywords*—** Benthic, Environmental Assessment, Jajrood river, Water Quality.

I. Introduction

THE increasing recognition that ecosystems perform services to mankind , keeping the planet fit for living and providing much of our ‘quality of life’ [1] , has led to an ecological approach [2,3] , to natural resource management that underlies sustainable development . Aquatic ecosystems require water to maintain the physicochemical structures , species , communities , processes and functions that give them their specific character. Thus , water allocated for the environment means indirectly supporting people by maintaining valuable ecosystem goods and services , [4] . Benthic macroinvertebrates , as one of the most important elements of aquatic ecosystems , are considered bioindicators of water quality in rivers because of their quick response to slight changes in the available environmental condition. An assessment of water quality through the aquatic community of benthic macroinvertebrates is based on the use of biotic indices and metrics .

This type of assessment can reveal important information about the environmental status of aquatic ecosystems [5]. Natural flow regimes in the Jajrood River are modified by Latian Dam transfers and a variety of hydraulic uses.

Licensing water use demands the environmental assessment for water abstractions from running waters because of the need to protect the natural environment according to the Water Framework Directive . Considering the above , the present study on the environmental assessment of the downstream ecosystems of Latian Dam uses benthics as a biological index of water quality.

II. Materials and Methods

The study area is part of the Jajrood River and is located in the downstream section of Latian Dam in the northeast of Tehran province. According to research on the plan of the Jajrood River catchment and a river length survey in field operations to assess the environmental assessment of the downstream ecosystems, the following factors are considered: discharge, water velocity, tributaries and topography, villages, situation of residential regions and bridges, and arriving place of the pollution and sewage of nearby factories. Finally, four sampling sites were selected with appropriate distances from each other at the length of Jajrood River, as shown in Table I. To determine the season of sampling , the average of the minimum absolute temperature of the nearest station (Abali station) was used. In this case, by cluster analysis, the nearest seasons from the point of temperature were classified into one group. The cluster analysis indicated that there are three true seasons in Jajrood River. According to cluster analysis, October, April, and May are in one group. June, July, August, and September are in another group, and November, December, January, February, and March are in one homogenous group. In this research, sampling was performed during the fall-winter season and spring. Also, the sampling time was determined in the middle of each season.The benthic macroinvertebrates were sampled in the fall-winter (2008) and spring (2009) seasons. At each sampling site, four substrate sub-samples were randomly collected using a 90-cm surber collector with a .0250 mm mesh size. The mean of four sub-

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samples at each sampling site were calculated to represent one sample. The samples were packed into special plastic cans and were labelled, fixed in 90% ethanol and transported to the laboratory for processing. The benthic macroinvertebrates were identified at the family level using binoculars and a specific identification key,and they were subsequently confirmed by specialists [6].

The water quality downstream of Latian Dam was assessed from campus macroinvertebrate surveys using Hilsenhoff's [7] , family-level Biotic Index (FBI). The FBI values were calculated using (1) . FBI is one of the most comprehensive and reliable metrics used to determine water quality [8]. Consequently, it is also widely used and is helpful for comparative purposes. Hilsenhoff placed the FBI values into a graded scale to numerically rate water quality, as shown in Table II. At this scale, higher FBI values indicate more degraded water quality. Mean monthly and seasonal flow data were obtained for the Jajrood River catchment froma water resource research organisation. Mean monthly and seasonal rainfall data were also obtained from the Bureau of Meteorology. Both rainfall and flow data covered a period of 30 years (water year 1976-77 to water year 2006-07). During these years, the regional hydrometric and rainfall gauging stations showed the highest statistics and were nearer to what they are today. The correlation method was used to rebuild incomplete statistics, homogenous annual discharge, and rainfall statistics confirmed using a sequence test.

III. *Results and discussion*

At the rainfall gauging stations at Afje , Narvan, and Great Lavasan, February had the maximum average monthly rainfall . At the Roodak, Garmabdar, and Latian stations, December, April , and March had the maximum average monthly rainfall. At all selected rainfall gausing stations, as shown in Table III, July, August, and September had the minimum average monthly rainfall . All stations reported the most rainfall in the winter season, and spring , fall and summer had the least rainfall. The Jajrood River catchment was full of water at the Roodak, Latian , and Narvan stations in May, with 24.5-26.5% of the total flow water volume. In April, Najarkola station had 29.08% of the total flow water volume, and it was full of water at this time of year. In August, the Roodak, Narvan, and Najarkola stations had 1 to 3% of the total flow water volume. In February, Latian station had 2.2% of the total flow water volume, and it had the minimum water at this time of the year. In all selected hydrometric stations, as shown in Table IV, spring was the wettest season of the year. A proportional distribution of discharge in spring was variable between 62.3% to 57.4% at these stations. Summer had the minimum flow water for Narvan and Najarkola stations, with 5 to 5.31% of the total annual flow water volume.The total annual flow water volume at Roodak station was 10.7% in fall and 10.3% in winter at Latian station, were the driest seasons as shown in Tables V to VIII. The seasonal changes of the benthic family abundance tended to increase from fall-winter to spring. The benthic family abundance also had an increasing trend from stations 1 to 4 (downstream to upstream) in the spring season, as shown in Table IX. The maximum and minimum benthic family abundance in fall-winter was found at stations 3 and 1, respectively, as shown in Table X . Seven (7) families from four (4) orders in fall-winter and thirteen (13) families from nine (9) orders in spring were found among the benthic samples. Orders such as Ephemeroptera, Trichoptera, Diptera ,Hydracarina , were found among the two seasons. Orders such as Pulmonata , Hemiptera , Odonat , Amphipoda ,Oligochaeta were found only in spring . Using the Hilsenhoff Biological Index equation and the classified water quality table, the Hilsenhoff Index was determined for each station and sampling season .The water quality and degree of organic pollution at each station was distinguished based on the Hilsenhoff Biological Index, as shown in Table XI.The rainfall and flow water patterns in the Jajrood catchment exhibited seasonal differences. Based on the results obtained from the Bureau of Meteorology and water resources research organisation records for rainfall and flow water patterns, it is clear that the dry season is summer-fall , and the wet season is spring-winter in the Jajrood catchment. In the dry season, the range of discharge observed was between 0 and 16.2 m^3/s, while in the wet season , the range was 0.2-49.5 m^3/s. In present study, a paired t-test was performed to investigate the effect of season on benthic family abundance and to indicate the environmental condition changes according to the season in Jajrood River (Figs.1 to 6). The relationship between the benthic community structure and environmental variables has been the subject of numerous investigations [9,10,11,12]. Poff and Ward [13] identified stream flow variability as a major factor affecting other abiotic and biotic factors that regulate lotic macrobenthic patterns.Benthic macroinvertebrates can be used as a biological index of water quality downstream of Latian Dam for several reasons.

Because benthic faunas have limited mobility, they are not able to avoid adverse conditions .In addition , these faunas are exposed to contaminants accumulated in the sediment, thus reflecting local environmental conditions [14] . A spill of a hazardous substances in waters may disappear after a period of time while the benthic faunas remain depressed.The results of the FBI indicate that the downstream area of Latian Dam exhibited average water quality at three sampling sites, and only one site exhibited good water quality.The number of benthic macroinvertebrates obtained during the study period is shown in Tables IX and X . A total of thirteen (13) families belonging to nine (9) orders were recorded, and the highest percentage of benthic macroinvertebrate family occurrence downstream of Latian Dam was Chironomidae and Caenidae.This result is similar to the findings of Ebrahim Nejad [15] in the Zayande Rood River. Chironomidae is commonly found in freshwater with considerable organic debris. The investigation of the density and diversity of benthics as observed from the study indicates that both are greater in spring than fall-winter. Considering the importance of benthics as a river biological index and using its benefits to assess water quality, similar research will be of great help for assessing the effects of development projects of water resources in downstream ecosystems.

TABLE I
FEATURES AND NUMBER OF SAMPLING SITES

Altitude (m)	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Site
1,900	35-47-0	51-41-0	1
1,890	35-47-8	51-40-45	2
1,680	35-47-13	51-40-51	3
1,600	35-47-19	51-40-50	4

TABLE II
HILSENHOFF FAMILY BIOTIC INDEX EXPLANATION

Family Biotic Index	Water Quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial organic pollution likely
5.76-6.50	Fairly poor	Substantial organic pollution likely
6.51-7.25	Poor	Very substantial organic pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

TABLE III
REGIONAL SELECTED RAINFALL GAUGING STATION FEATURES

Altitude (m)	Latitude (degree,minute)	Longitude (degree, minute)	Station
1,690	35-51	51-33	Roodak
1,560	35-47	51-41	Latian
1,750	35-50	50-40	Narvan
2,500	35-59	51-39	Garmabdar
2,200	35-49	51-47	Great Lavasan
1,790	35-51	51-42	Afje

TABLE IV
REGIONAL SELECTED HYDROMETRIC STATION FEATURES

Area $(km)^2$	Altitude (m)	Latitude (degree, minute)	Longitude (degree, minute)	Station
416	1,690	35-51	51-33	Roodak
710	1,560	35-47	51-41	Latian
30	1,750	35-50	51-40	Narvan
59	1,700	35-49	51-38	Najarkola

TABLE V
SURFACE FLOW WATER SEASONAL CHANGES AT ROODAK STATION

Season	Fall	Winter	Spring	Summer
Volume (MCM)	26.2	38.8	145.4	33.01
Proportional distribution %	10.7	15.9	59.7	13.5

TABLE VI
SURFACE FLOW WATER SEASONAL CHANGES AT NARVAN STATION.

Season	Fall	Winter	Spring	Summer
Volume (MCM)	1.3	2.5	7.5	0.6
Proportional distribution %	10.8	21.4	62.3	5.3

TABLE VII
SURFACE FLOW WATER SEASONAL CHANGES AT LATIAN STATION

Season	Fall	Winter	Spring	Summer
Volume (MCM)	24.7	19.2	107.3	32.5
Proportional distribution %	14.8	10.3	57.4	17.4

TABLE VIII
SURFACE FLOW WATER SEASONAL CHANGES AT NAJARKOLA STATION

Season	Fall	Winter	Spring	Summer
Volume (MCM)	3.1	5.8	14.9	1.2
Proportional distribution %	12.4	23.01	59.4	5

TABLE IX
BENTHIC AVERAGE ABUNDANCE IN SPRING

	Order	Family	ST.1	ST.2	ST.3	ST.4
1	*Ephemeroptera*	*Baetidae*	5	25	17	27
		Caenidae	17	254	126	210
2	*Trichoptera*	*Hyropsychidae*	2	69	16	4
		Rhyacophilidae	-	-	15	1
3	*Diptera*	*Thaumaleidae*	6	-	6	7
		Chironomidae	18	4	129	252
4	*Hydracarina*	*Acariformes*	4	17	19	6
5	*Pulmonata*	*Physidae*	1	2	24	3
6	*Hemiptera*	*Pleidae*	-	1	7	7
7	*Odonata*	*Platycnemidae*	-	-	-	1
		coenagrionidae	-	1	1	1
8	*Amphipoda*	*Gamaridae*	-	-	3	3
9	*Oligochaeta*	*Lumbridae*	-	-	89	-

TABLE X
BENTHIC AVERAGE ABUNDANCE IN FALL-WINTER

	Order	Family	ST.1	ST.2	ST.3	ST.4
1	*Ephemeroptera*	*Baetidae*	1	5	3	10
		Caenidae	5	26	31	31
2	*Trichoptera*	*Hyropsychidae*	-	16	10	1
		Rhyacophilidae	-	-	6	-
3	*Diptera*	*Thaumaleidae*	1	-	1	4
		Chironomidae	5	10	27	17
4	*Hydracarina*	*Acariformes*	-	5	8	2

TABLE XI
WATER QUALITY CLASSIFICATION AT THE SITES IN TWO SAMPLING SEASONS BASED ON THE HILSENHOFF INDEX

Sampling season	Site	Hilsenhoff Index	Degree of Organic Pollution
Fall-winter	1	6.4	Substantial organic pollution likely
	2	5.08	Fairly substantial organic pollution likely
	3	5.6	Fairly substantial organic pollution likely
	4	6.06	Substantial organic pollution likely
Spring	1	5.9	Substantial organic pollution likely
	2	5.4	Fairly substantial organic pollution likely
	3	6.2	Substantial organic pollution likely
	4	6.8	Very substantial organic pollution likely

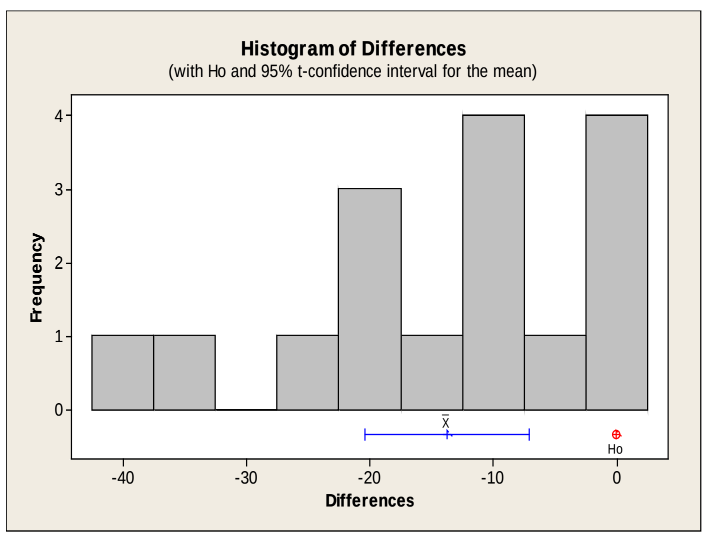

Fig. 1 Seasonal difference of Baetidae family abundance

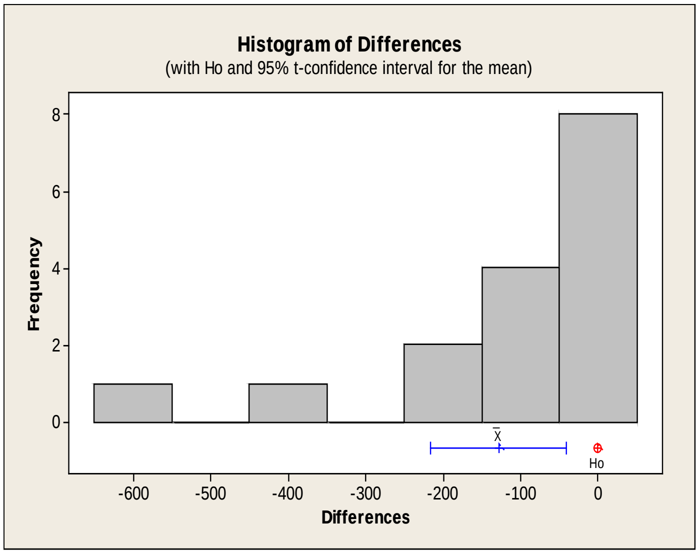

Fig.2 Seasonal difference of Caenidae family abundance

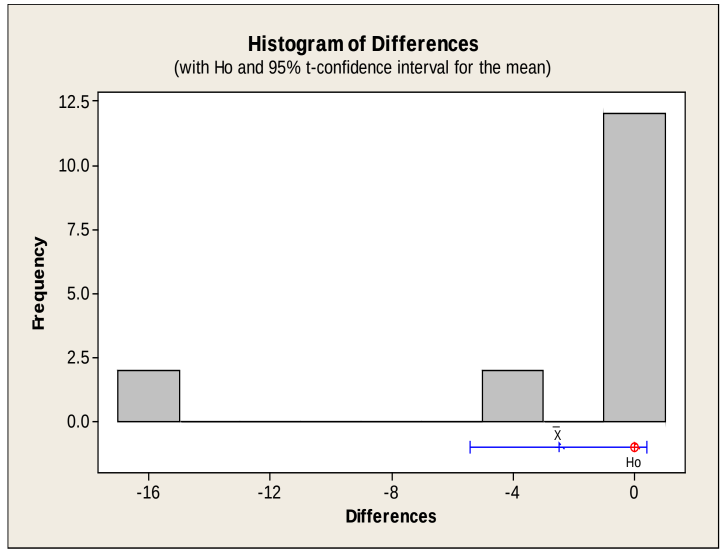

Fig. 4 Seasonal difference of Rhyacophilidae family abundance

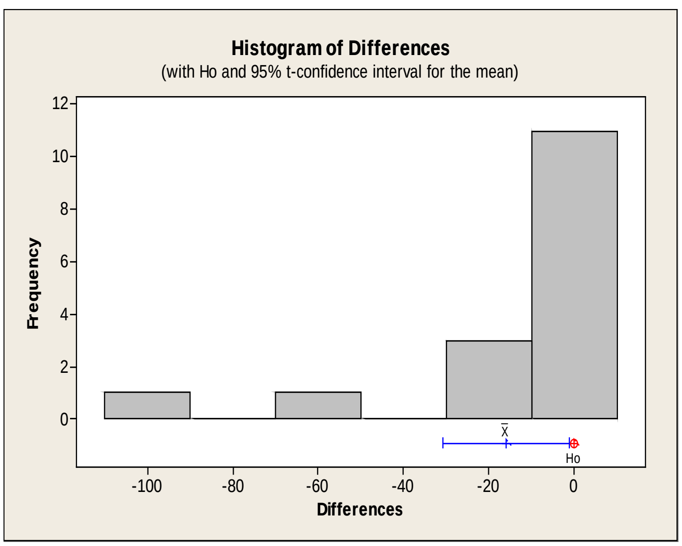

Fig. 3 Seasonal difference of Hydropsychidae family abundance

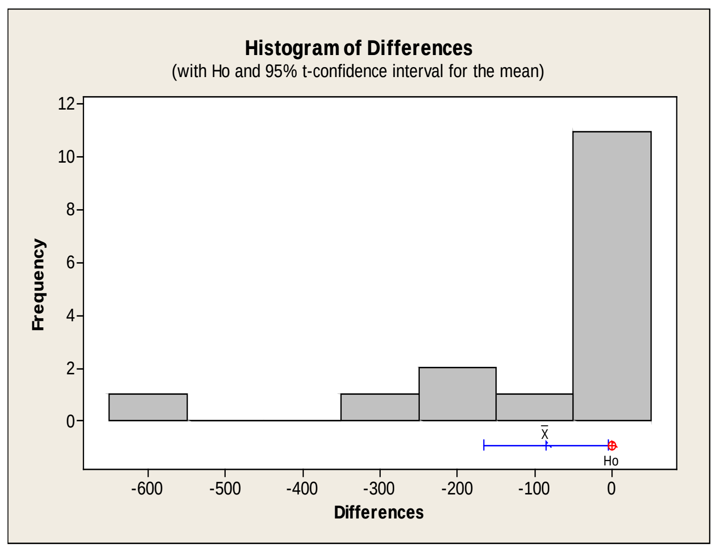

Fig .5 Seasonal difference of Chironomidae family abundance

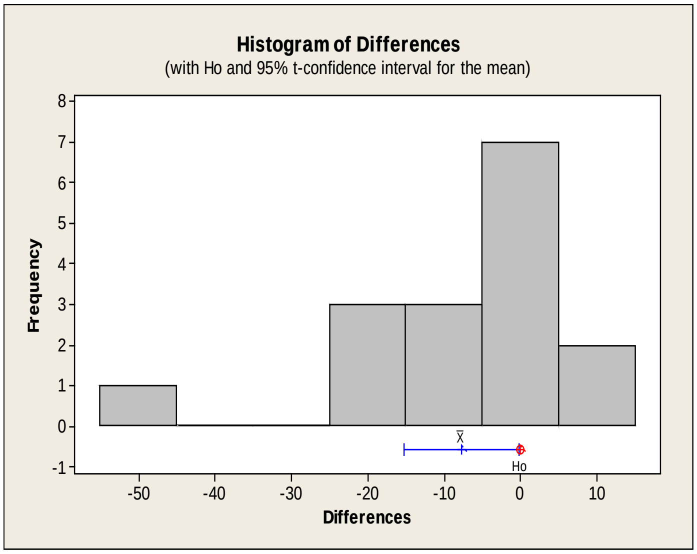

Fig .6 Seasonal difference of Acariformes family abundance

$$FBI = \Sigma\, n_f\, t_f / N \qquad (1)$$

where:
n_f=the individuals of a family in the sample
t_f=the tolerance value of the organic pollution of a family
N=the total number of individuals in the sample

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