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Effects of land use change on macroinvertebrate community composition in upper reaches of the Chehel-Chai chatchment, Iran

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ABSTRACT

Urbanization of catchment regions is a major cause of freshwater ecosystem degradation worldwide. As catchments become more developed and river ecosystems become increasingly engulfed in various land use activities, there is a growing need to understand these impacts on freshwater ecosystems. Macroinvertebrate are extensively used as indicators of ecosystem health and have been an instrument tool in ecosystem monitoring and management. Five stations with different types of land use (reference station, forest, recreational, agricultural, urban area) of Chehel Chai River, Iran were sampled in 2018. A total of 2040 macroinvertebrate belonging to 6 orders from 12 families were identified. The highest abundance was related to the diversity of the Ephemeroptera (Batidae). According to the results, the abundance of macroinvertebrate was significantly different in the seasons and sampling stations. The maximum value of diversity indices was measured to the Shannon index (S1= 1.06, autumn), Simpson's Index (S1= 0.63, autumn), Margalef richness (S1= 0.9, spring) and Pielou's index (S3= 0.92, summer). Stations in up-stream (forest area) recorded highest species richness, abundance and proportion of sensitive macroinvertebrates compared to the agricultural and urban development area. Cluster and nMDS analysis revealed that among the macroinvertebrates, Ephemeroptera were distinct in the forest sites and Diptera and Oligochaeta in urban area of Chehel Chai River. This finding suggests that present environment problem (such as: agriculture, tourism and urban area) caused serious impacts on the biodiversity of Chehel Chai River.

Keywords: Benthic macroinvertebrates, Land use, Diversity, Chehel Chai River.

INTRODUCTION

Land-use changes and vegetation cover are one of the most important factors in hydrological regime change, erosion process, and biodiversity status. Since land-use type can positively and negatively affect water quality and biological communities, therefore it is necessary to determine the extent of impact and contribution of different types of land use in surface water supply areas. Environmental impacts of land-use change on current water ecosystems increase environmental impacts at large spatial scales. Agricultural activities can lead to soil erosion and runoff, which causes large amounts of soft sediment deposition in streams and rivers (Palmer *et al.* 2002). Investigation of quantity and quality of pollutant sources, determination of qualitative status and presentation of a suitable model for investigating spatial and temporal variations of pollutants are the most important components of water quality (Imanpour Namin *et al.* 2013; Gholizadeh 2021). The pollution of rivers with pollutants caused by anthropological factors can be considered as an indicator of environmental pollution. Because rivers are the only water resources that go a long way through cities, villages, agricultural and industrial areas and are used more than any other sources for various applications, they can have adverse effects on the environment (Rosenberg & Resh 1993). Therefore, identifying the status of river water quality is an important issue. Currently, most of the available fresh water in Iran is flowing into the lotic ecosystems. Therefore, proper management is essential. The basis of water resources management is its evaluation (Xiao-jun *et al.* 2012). The first step is to identify living

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organisms and the environmental factors that inhabit that ecosystem. The basis of this recognition is its ecological examination. Physical and chemical changes in water indicate contamination at the time of sampling. However, ecological data show long-term changes in the ecosystem due to water pollution (Barakat *et al*. 2016). According to the US Environmental Protection Agency, the best way to evaluate aquatic ecosystems is to use the ecological relationships of living organisms with the same ecosystems as ecological indicators called ecological evaluation (Flotemersch *et al*. 2017). A good water quality assessment should include important aquatic life, such as macroinvertebrates (Aazami *et al*. 2015). Many studies have been conducted to evaluate the ecological aquatic ecosystems due to the effects of the physical, chemical and biological factors on benthic macro-invertebrates (Nessimian *et al.* 2008; Bucker *et al*. 2010; Jun *et al.* 2011; Foomani *et al.* 2019). Because of their inability to escape contamination, relatively long life, easiness of sampling and identification, low cost, and variable susceptibility to pollution are good indicators for understanding water health (Van Ael *et al*. 2015). They illustrate the cumulative effects of multiple stressors such as habitat degradation that are not observable by traditional water quality (physico-chemical) assessment methods. Macroinvertebrates have a sensitive place in the food chain of the water courses and are therefore easily sampled and identified. Macro-invertebrates have a sensitive place in the food chain of the water currents and are therefore easily sampled and identified (Aazami *et al*. 2015). Chehel Chai River located in Minoodasht City, Golestan Province, Iran and plays an important role in the social and economic life of the inhabitants in this region and is also important for agricultural, aquaculture and water supply purposes. Since no research has been conducted on the health status of this ecosystem, the present study has considered this issue. The main purpose of this study was to evaluate the quality status of Chehel Chai River using macroinvertebrate communities and biological indices.

MATERIALS AND METHODS

Study area and sampling procedure

The Chehel Chai catchment area is approximately 25,000 hectares in the northern slopes of eastern Alborz. The study basin is located at the east longitude of 55° 22' 30" to 55° 37' 30" and the north latitude of 36° 57' 30" to 37° 15' 00". The annual rainfall is 766.5 mm. The hydrological flow of the Chehel Chai basin has a significant impact on the economy of the basin and out of the basin as well as the fertile and desirable lowlands of the Gorganroud River (Lakzaei *et al.* 2018). The dominant vegetation of the basin in the northern part is the forest and in the south, it changes to dry and grassland type. The height difference between the highest and lowest points is 1380 meters (Department of Agriculture, Gorgan and Gonbad 2005). The discharge of the Chehel Chai River is minimal during the summer months due to the exploitation of rivers to irrigate the riverside farms (Golestan Watershed Management 2014). In addition, about 90% of water in Chehel Chai basin is used for agricultural activities and another portion is used for industrial use (Ravanab Consulting Engineering Company 2005).

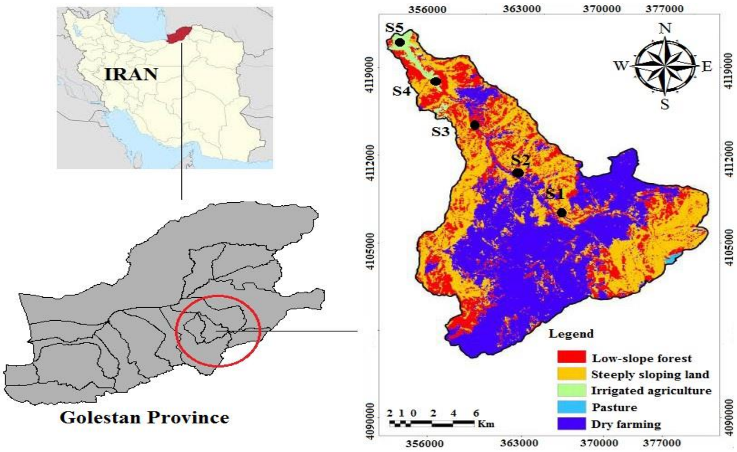

Fig. 1. Location of the sampling stations in the Chehel Chai River, 2018.

Its watershed can be divided into five geomorphological areas according to the type of land use: 1- native forest area in upstream region; 2- a wide range of highland agriculture from the upper to middle region; 3- as well as tourist and recreational area in the lower region; and 5- residential area (Minodasht City). To prepare land use map of Chehel Chai watershed from satellite image of Landsat 7, ETM^+ band in 2015 with a spatial resolution of

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533 Received: Feb. 03. 2021 Accepted: May 16. 2021
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30 m was used. Regarding the field visit and considering the low land use diversity in the study area, the normalized difference vegetation index was selected for image classification. This indicator reveals the difference between coverage and non-coverage parts. So, image bands were separated and was imported into IDRISI software. Then, by controlling the threshold for change of land use, the detection of image changes was performed and the image was classified according to the supervised method. To evaluate the accuracy of the maps provided with terrestrial reality, point terrestrial control points were randomly (using global positioning system and point coordinates) transferred to ArcGIS 10.6.1 environment for definition and interpretation. We implemented Pearson correlation analysis (SPSS v24) to assess the correlation between the major land use categories and the macroinvertebrate community. Macroinvertebrates were sampled seasonally in 4 times (May, August, November and February) during 2018 from five stations using Surber sampler (0.09 m^3) with 3 replications in the complete water mixing area. The benthic specimens collected after separating the unwanted material using standard sieves with a 500-micron mesh were fixed in 4% formalin and transferred to the Laboratory in Gonbad Kavous University. The locations of the sampling stations are shown in Fig. 1 and the geographical coordinates of the stations are displayed in Table 1. After transferring the specimens to the laboratory and washing for separation, the specimens were counted and identified using stereo microscope according to the Family Identification Keys (Thorp & Covich 2009; Needham 1976).

Table 1. Characteristics of the sampling station in the Chehel Chai River.

Stations	Land use	Geographic coordinates	Width (m)	Altitude (m)
S1	Reference area	36° 59' 77'' E, 41° 09' 91'' N	2.5	135
S2	Native forest	36° 37' 09'' E, 41° 13' 74'' N	8.4	210
S3	Recreational area	36° 13' 40'' E, 41° 16' 69'' N	6.7	324
S4	Agriculture impact	35° 84' 42'' E, 41° 20' 52'' N	3.6	511
S5	Urban area	35° 53' 17'' E, 41° 20' 48'' N	2.3	721

Statistical processing and data analysis

Two-Way ANOVA and Tukey’s HSD test were carried out using the software SPSS 24. The biological indices of Shannon-Wiener (H’), Simpson (1−D), Margalef richness index and Pielou were calculated in terms of abundance using the PRIMER v.6. The difference of macroinvertebrates was investigated using cluster analysis and non-metric multidimensional scaling (n.MDS) and also using Bray-Curtis relative similarity index in PRIMER v.6. ANOSIM and SIMPER analyses were conducted using the PRIMER v.6 (Clarke & Gorley 2006). The statistical significance of the species indicator values was estimated using a random reallocation procedure (1000 randomizations; Monte Carlo test) of sites among site groups. A species is considered a group indicator if the results are significant to a level of 0.05 (Zintzen *et al.* 2008). The IndVal coefficient was calculated using the PC-ORD v.4.0 program for Windows (McCune & Mefford 1999).

RESULTS AND DISCUSSION

Six orders with 12 families consisting of 2040 individuals in Chehel-Chai River were recorded during the sampling period (Table 2). Baetidae (695 ind, 34.07%) and Chironomidae (460 ind, 22.55%) were the dominant families in this study. Aquatic insect larvae were the most abundant among the large population of macroinvertebrates. The highest diversity belonged to Diptera order with 5 families, as well as Ephemeroptera and Gastropoda orders with 2 families, respectively. The role of aquatic invertebrates in the transmission of energy flow in aquatic ecosystems has particular importance and the study of benthic communities is an appropriate criterion for assessing the ecological status of aquatic ecosystems (Gholizadeh & Heydarzadeh 2019). Based on the comparison of the upstream (St. 1) to downstream (St. 5, in urban area) of Chehel Chai River, the susceptible organisms were more abundant and diverse in the upper stations (in pristine and forest area with good water quality) than the lower stations (in urban area). The opposite was observed for resistant organisms. Other studies have shown that human activities such as rural, industrial and agricultural effluents import large amounts of pollutants into the aquatic environment and affect the diversity and abundance of macroinvertebrates (Martzeni & Esteve 2007). In this study, resistant organisms (Simuliidae and Chironomidae) were more abundant in stations 4 and 5 than in upstream stations (St. 1-2). The most important factors in the abundance increase of these groups at the stations 4 and 5 were agricultural and urban wastewaters. Chironomidae is a common organism in most aquatic habitats and is one of the resistant communities in the disturbances of the aquatic environments. This

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533 Received: Feb. 03. 2021 Accepted: May 16. 2021
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benthos is used in the detection of human disturbances in medium-sized rivers (Çetinkaya & Bekleyen 2017). Anthropogenic activities in the middle part of the river can lead to an increase in filtering groups (*Simulium* sp.), resistant groups (Oligochaeta and Diptera orders), and a decrease in susceptible groups (such as Perlidae). The number of Ephemeroptera species was highest at four upstream stations and decreased at St. 5 (in urban area) which indicates an increased water pollution from upstream to downstream. Gastropoda and Tubificidae species were observed at stations 2 (in forest) and 4 (in agricultural area) that are able to withstand adverse conditions such as low soluble oxygen and high concentrations of pollutants (Deborde *et al*. 2016). The Perlidae was the only identified family belong to this order at the studied stations. Psychodidae and Dixidae were not observed in autumn. Oligochaeta was only observed in downstream stations (St. 4-5) that were most affected by Anthropogenic activities, including high agricultural activity and urban area (Table 2).

Table 2. The abundance of macro-invertebrates (ind) identified in Chehel Chai River, 2018.

Order	Family	S1	S2	S3	S4	S5
Plecoptera	Perlidae	3	-	-	-	-
Ephemeroptera	Baetidae	172	233	108	68	122
	Caenidae	31	134	67	42	8
Tricoptera	Hydropsychidae	66	126	138	25	6
Diptera	Pupa-Chironomidae	-	-	5	7	3
	Chironomidae	-	28	86	80	266
	Simuliidae	-	15	32	21	40
	Ceratopogonidae	-	-	4	8	-
	Psychodidae	-	-	10	16	-
	Dixidae	-	-	5	8	-
Gastropoda	Physidae	-	7	-	1	-
	Lymnaeidae	-	3	-	1	-
Oligochaeta	Tubificidae	-	-	-	14	39

The results showed that Ephemeroptera (977 ind, 47.89%) and Diptera (634 ind, 31.08%) had the highest abundance, while Plecoptera (3 ind, 0.15) and Gastropoda (12 ind, 0.59) exhibited the lowest one (Fig. 2). Plecoptera order (3 individual) had 0.15% of the macrobenthic invertebrate population in this river, and Gastropoda order (4 individual) by 0.59% was observed only in spring and autumn. The abundance of macroinvertebrates in the seasons and sampling stations are shown in Fig. 3. The highest abundances of macroinvertebrates were observed in St. 2 (229 ind, 25.78%) and St. 5 (140 ind, 13.68%) in winter. Also, the lowest percentages were observed at St. 1 (0.54%) and St. 4 (91%) in spring followed by St. 4 (1.72%) in summer. Fig. 4 depicts the highest abundance in winter (844 ind, 41.3748%) and autumn (555 ind, 27.21%), respectively. In addition, macroinvertebrates displayed a significant difference between sampling stations and seasons ($P > 0.05$) (Table 3). The highest abundance and diversity of macroinvertebrate communities were observed in winter and autumn due to the provision of suitable environmental conditions such as reduced agricultural activities, increased discharge, as well as river self-refining and food availability. The lowest abundance was observed in spring (12%) and summer (15%) (Fig. 3b). The entrance of agricultural water drains (rice, rapeseed, and wheat) containing chemical fertilizers, elevates river water phosphate, and also unfavorable river conditions including low discharge cause environmental problems (decreased diversity and increased resistant species) in summer (Department of Agriculture, Gorgan and Gonbad 2005).

Table 3. The Two-Way ANOVA results on the influence of stations, seasons and interaction between stations and seasons on the abundance of macroinvertebrates within Chehel Chai River.

Variable	df	Mean square	Sum of squares	F	P-value
Season	3	24977	74933	7239	0.001
Station	4	6215	24863	1801	0.001
Station × Season	12	1852	22229	536	0.001
Residual	20	3	69	-	-
Total	40	24977	528118	-	-

Df = degrees of freedom, F = MS factor/MS residual and p = probability of significance; α = 0.05.

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533
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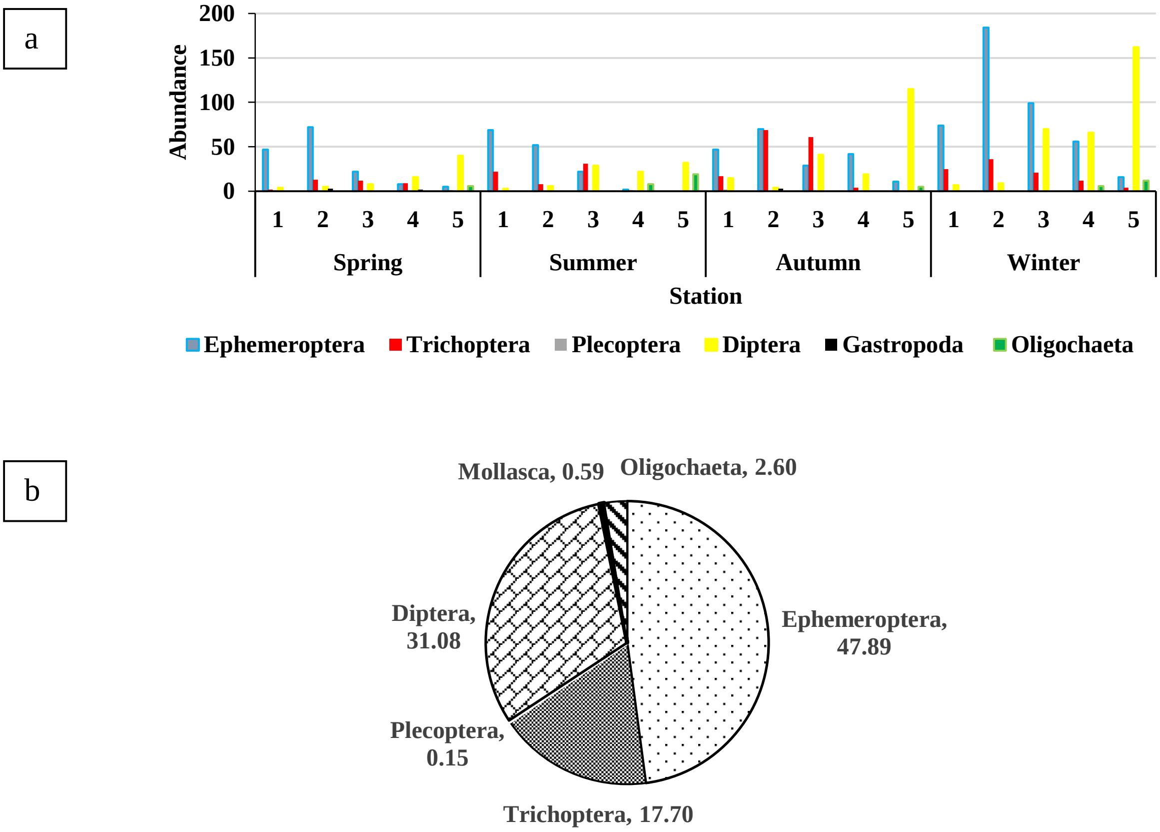

Fig. 2. Abundance (a) and percentage (b) of macroinvertebrates during the sampling period.

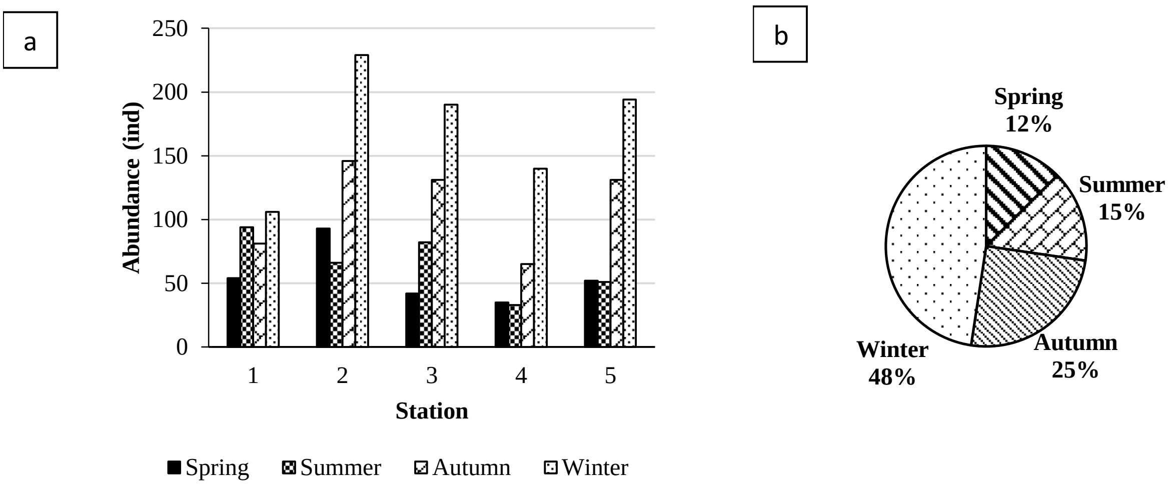

Fig. 3. Abundance (a) and percentage (b) of macroinvertebrates at different sampling stations and seasons.

The diversity indices based on Shannon-Weiner and Simpson Indexes showed the same results comparing aquatic insects between the five sampling stations (Fig. 4). The value was highest in St. 1 (in reference area) during autumn (1-D = 0.63; H' = 1.06) and in St. 3 (in recreational area) during summer (1-D = 0.62, H' = 1.01) compared to St. 5 (in urban area) during summer (1-D = 0.21, H' = 0.42) and station 5, spring (1-D = 0.26, H' = 0.51). The results were similar with taxa richness for both highest and lowest values. The Shannon-Wiener diversity values found in this study ranged from 0.42 to 1.06. Studies with a more even station distribution amongst season may obtain more useful Shannon diversity results. Stations in spring, summer, autumn and winter revealed an average Shannon diversity scores of 0.79, 0.71, 0.86 and 0.78 respectively (Fig. 4).

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533
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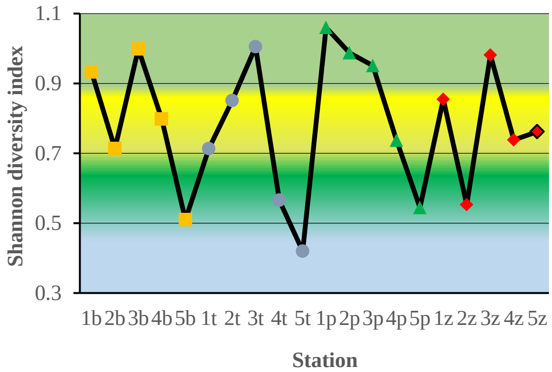
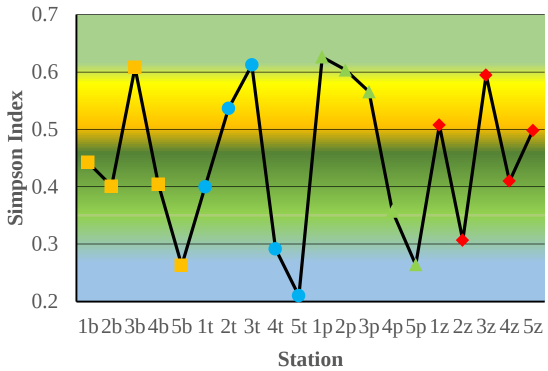
Minor relationships can be observed between the sampling stations in different seasons and the Margalef index results. For instance, some of the highest Margalef index values were recorded in St. 1 during spring (d = 0.9). Stations 1 and 2 (in reference and forest areas) during winter (d = 0.33, 0.35) exhibited a lower average Margalef index than other stations. However, the station-to-station variation is undeniable, with no obvious patterns (Fig. 4). The Pielou index values found in this study ranged from 0.38 to 0.92. The stations in spring, summer, autumn and winter displayed an average Pielou index values of 0.64, 0.62, 0.69 and 0.68, respectively (Fig. 4).

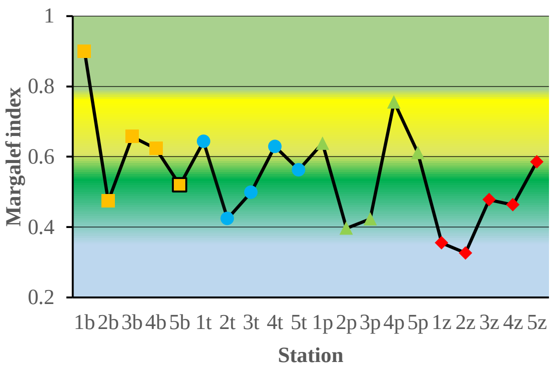
Shannon-Weiner Index	Studied stations	
	Rate (%)	No. of station
<0.5	5	1
0.5-0.7	20	4
0.7-0.9	40	8
>0.9	35	7



Simpson Index	Studied stations	
	Rate (%)	No. of station
<0.3	20	4
0.3-0.4	10	2
0.4-0.5	35	7
0.5-0.6	15	3
>0.6	20	4



Margalef index	Studied stations	
	Rate (%)	No. of station
<0.4	15	3
0.4-0.6	45	9
0.6-0.8	35	7
>0.8	5	1



Pielou index	Studied stations	
	Rate (%)	No. of station
<0.5	15	3
0.5-0.7	45	9
0.7-0.9	30	6
>0.9	10	2

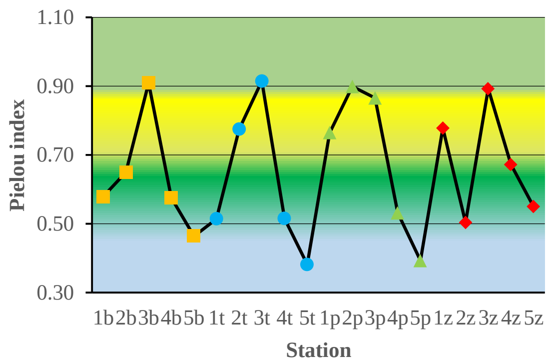


Fig. 4. Diversity index values for each sampling site, displayed upstream to downstream, along the Chehel-Chai River. Numbers = stations, b = spring, t = summer, p = autumn, z = winter. Reference station: number 1, Native forest: number 2, Recreational Land: number 3, Agriculture impact: number 4, Urban station: number 5.

The community structure index is a composite measure of biological structure that combines the number of species (richness) and the distribution of individuals among species (evenness). Diversity indices depend on the quality and availability of habitats (Barbour *et al.* 1999). They reflect the impact of all stressors independent of ecological boundaries. According to the results, the highest values of Shannon-Wiener (H) and Simpson (1-D) diversity were observed at St. 1-2, which may be due to the rich and intact habitat structure. Also, the lowest values were observed

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in the downstream (at St. 5). Low values of these indices indicate pollution or turbulence in the river environment. The Shannon-Wiener diversity values found in this study ranged from 0.42 to 1.06. As with the other macro-invertebrate indices, most of the sampling stations in different seasons do not show an obvious relationship to the Shannon diversity index. For instance, the stations during spring, autumn and winter all fall within similar Shannon diversity ranges, whereas summer contains a high variety of results. Studies with a more even station distribution amongst season may obtain more useful Shannon diversity results. Other biological indicators follow a similar trend and show an overall increase in nutrient contamination, especially along the downstream river. The results of indicator species analysis showed that different land use areas were different in terms of species, such that an indicator species for each land use can be introduced. In this study, forest and urban areas had 4 indicator species, while the recreational and agricultural areas exhibited 2 and the reference station only 1 (Table 4). Considering the definition of stations into groups using land use, the indicator value (IndVal) coefficient revealed thirteen significant indicator taxa. However, based on IndVal scale proposed, only four species revealed high indicator values (> 50%). The Perlidae belonged to group 1 (in reference station), Caenidae belonged to group 2 (in forest), Chironomidae and Tubificidae belonged to group 5 (in urban area). The results showed that there was a significant difference in the abundance of macro-invertebrates between the stations and the different seasons. However, there was no significant difference in the biodiversity between the different seasons, although there was a significant difference between stations. In addition, the diversity of benthic species decreased from the upstream to downstream stations, similar to results reported by Gholizadeh & heydarzadeh (2019) and Van Ael *et al*. (2015).

Table 4. Indicator value (IndVal) coefficient for significant species related to the categorical groups.

Indicator species	Group*	Indicator value (IndVal)	P-value
Perlidae	1	51	0.054
Baetidae	2	33.5	0.26
Caenidae	2	55	0.015
Hydropsychidae	3	38.2	0.223
pupa Chironomidae	3	25	0.579
Chironomidae	5	58.5	0.025
Simuliidae	5	32.9	0.435
Ceratopogonidae	4	33.3	0.414
Psychodidae	5	29.2	0.377
Dixidae	4	34.1	0.131
Planorbidae	2	37.5	0.152
Physidae	2	37.5	0.275
Tubificidae	5	73.6	0.009

*- Groups: 1- Reference station, 2- Native forest, 3- Recreational land, 4- Agriculture and 5- Urban.

Table 5 shows the area of forest, agricultural, urban and tourism land uses based on the Landsat satellite map.

Table 5. Area of land use classes in year 2015.

Land use	Area (hectare)	Area (%)
Forest	14450.56	54.87
Agricultural	11229.97	42.64
Urban	653	2.48
Tourism	2	0.01

The results showed that the different land use types have a significant effect on macroinvertebrate communities. These effects include the negative effect of urban area and the positive effects of reference station and forest area on species diversity and biomarkers. These results are consistent with other studies on the impact of urban areas on macroinvertebrate communities (Sharifinia *et al.* 2012; Gholizadeh & Alinejad 2018; Villeneuve *et al.* 2018). Reduction in the diversity of aquatic insect communities at St. 5 confirmed that deforestation and deterioration of natural habitat quality by urban development trends is affecting aquatic insect diversity (Che Salmah *et al.* 2013; Gholizadeh & Boveiri 2019). Among the four land use variables considered, forest land use was positively correlated with Perlidae, while negatively correlated with Simuliidae. The agriculture land use was positively

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correlated with Caenidae, Hydropsychidae, Planorbidae and Physidae. The urban land use was negatively correlated with Baetidae, while positively correlated with Ceratopogonidae and Tubificidae. Tourism was negatively correlated Caenidae and Dixidae, while positively correlated with Chironomidae and Psychodidae (Table 5).

Table 6. The pearson correlation coefficients between macroinvertebrate community (all variables were ln-transformed) and watershed land use classes (area).

Indicator species	Forest	Indicator value Agriculture	Urban	Tourism
Perlidae	0.99*	-0.33	-0.33	-0.33
Baetidae	0.89	-0.11	-0.73*	-0.05
Caenidae	-0.16	0.86*	0.13	-0.79*
Hydropsychidae	0.08	0.9*	-0.38	-0.6
pupa Chironomidae	-0.63	0.27	0.63	-0.17
Chironomidae	-0.61	-0.15	-0.19	0.95*
Simuliidae	-0.78*	0.52	-0.32	0.59
Ceratopogonidae	-0.42	0.21	0.84*	-0.63
Psychodidae	-0.6	-0.41	0.14	0.88*
Dixidae	-0.66	-0.45	-0.35	-0.76*
Planorbidae	-0.33	0.99*	-0.33	-0.33
Physidae	-0.33	0.99*	-0.33	-0.33
Tubificidae	-0.48	-0.48	0.93*	0.03

The highest number of taxa was found in agriculture (8 taxa), while the lowest in reference (4 taxa) areas. The highest percentage of aquatic insects was observed in the forest (26%), while the lowest in the urban development (St. 5) areas (Fig. 5).

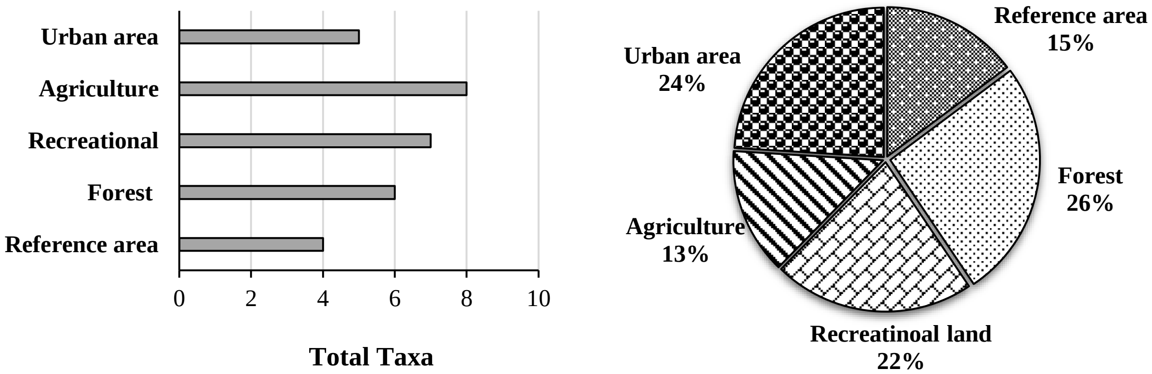

Fig. 5. Total taxa and percentage of macroinvertebrates in different land uses.

The ANOSIM results indicated significant differences ($p < 0.05$) between each pair of the land use groups in terms of the macroinvertebrate composition (Table 7). No significant differences were found between reference station and native forest, and also between recreational land and agriculture as well as between agriculture and urban ($p > 0.05$). SIMPER results revealed the highest average dissimilarity (65.65%) to be observed between St. 1 and St. 5 with the top seven contributor families including Chironomidae (24.79%), Baetidae (18.94%), Tubificidae (13.62%), Hydropsychidae (12.29%), Caenidae (8.08%) and Simuliidae (7.7%) and Psychodidae (5.12%). Sampling stations in aqriculture and urban area revealed the lowest average dissimilarity (30.7%) with top three contributor families including Hydropsychidae (29.1%), Tubificidae (14%) and Caenidae (12.7%). Within each season, the highest dissimilarity of benthic macroinvertebrate community was observed between autumn and summer (SIMPER average dissimilarity = 50.28%) with top four contributor families including Hydropsychidae (18.99%), Baetidae (17.91%), Chironomidae (16.73%) and Caenidae (14%), Simuliidae (11.69%), Tubificidae (9.04%). Based on clustering diagrams and non-metric multidimensional scaling (n.MDS) of identified samples in different land uses (reference station, forest, recreational land, agricultural and urban area), macroinvertebrate groups were divided into two groups at 64.79 similarity distance (Fig. 6). Sampling

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533
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stations of benthic invertebrate groups in a cluster indicate that the diversity and abundance of organisms in these locations are similar: Cluster 1 consists of downstream stations in the urban area (St. 5, mainly affected by the city effluent). Cluster 2 is also diverse and includes other sampling stations. In addition, cluster 2 has sub-clusters with short lengths which indicate intra-group similarity in these clusters.

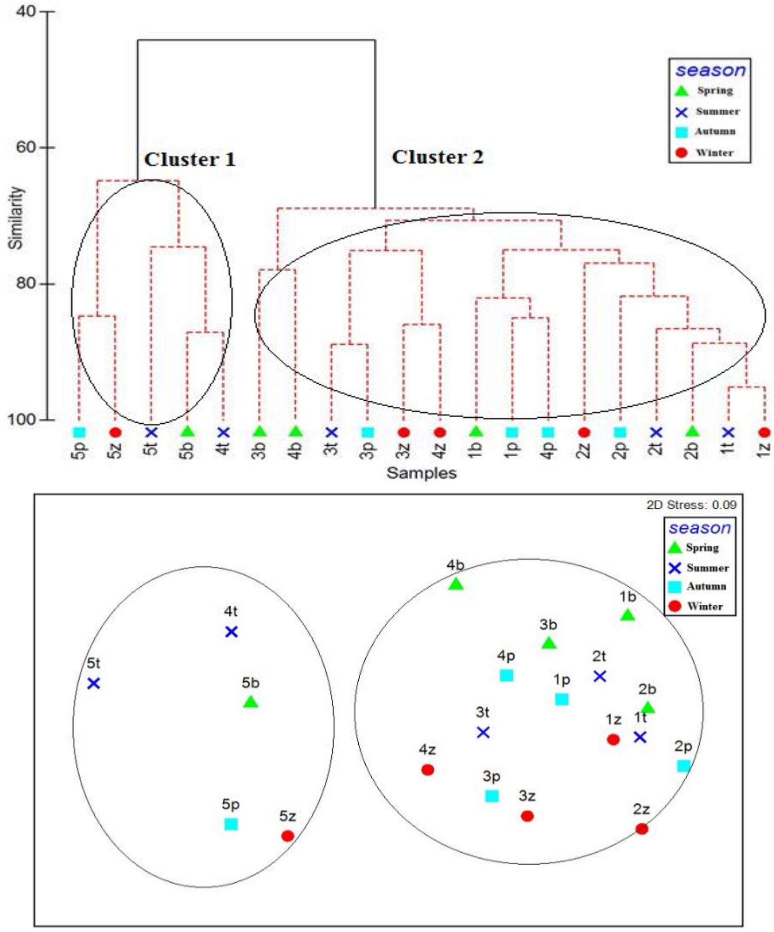

Fig. 6. Cluster and nMDS analysis of grouping (UPGMA, Bray-Curtis) based on square root transformed macrobenthos abundance data in sampling stations with different land use influences in Chehel-Chai River. Numbers = stations, b = spring, t = summer, p = autumn, z = winter. Reference station: number 1, Native forest: number 2, Recreational land: number 3, Agricultural impact: number 4, Urban area: number 5.

Table 7. ANOSIM results comparing macroinvertebrate taxa collected from different land use.

Groups	Rho	P-value
Reference area		
Forest	-0.12	0.77^{n}
Recreational land	0.46	0.03
Agriculture	0.38	0.03
Urban	0.97	0.01
Forest		
Recreational land	0.56	0.03
Agriculture	0.44	0.03
Urban	0.96	0.01
Recreational land		
Agriculture	0.16	0.14^{n}
Urban	0.89	0.03
Agriculture		
Urban	0.26	0.14^{n}

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CONCLUSION

The presence of some special species of macroinvertebrates, especially in the contaminated and non-polluted parts of a river, can be used as a potential indicator for river evaluation. Since the study of macroinvertebrates is not comprehensive in Iran, identification of these organisms in the Chehel Chai River is useful for further studies. More taxonomic work is usually needed to identify organisms at the species level. The study of Chehel Chai River showed that this river is not rich in diversity of benthic. Abundance was also high in some stations, while low in others. The application of bio-indicator can well explain the impact of anthropogenic activities on water quality changes at different stations. This method was used in the biological evaluation of the Chehel Chai River to assess the water quality at each station under major pollution factors (urban wastewater, agricultural and recreational area). In this study, the results of population composition and bio-demographic indices in different stations showed more severe effects of anthropogenic activities in downstream than in upstream stations. The destructive effects of human sewage and its impact on the aquatic ecosystem are not hidden to anyone, so it seems that proper planning and management can reduce the severity of the damage.

REFERENCES

Aazami J, Esmaili Sari A, Abdoli A, Sohrabi H and Van den Brink, PJ 2015, Assessment of ecological water quality with using physicochemical, fish and macroinvertebrates indices in Tajan River, Iran. *Journal of Environmental Health Science Engineering* 56:260-269, http://dx. doi.org/10.1007/s00267-015-0489-x.

Barbour M T, Gerritsen BD, Synder BD and Stribling J B 1999, Rapid bioassessment protocols for use in wadeable streams and rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd edn. EPA 841-b-99-002. United States Environmental Protection Agency, Office of Water, Washington, DC, 342 p.

Barakat A, El Baghdadi M, Rais J, Aghezzaf B and Slassi M 2016, Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. *International Soil and Water Conservation Research*, 4: 284-292, http://dx. doi.org/10.1016/j.iswcr.2016.11.002

Bucker A, Sondermann M, Frede H G and Breuer L 2010, The influence of land use on macroinvertebrate communities in montane tropical streams: A case study from Ecuador. *Fundamental and Applied Limnology* 177: 267-282, http://dx. doi.org/10.1127/1863-9135/2010/0177-0267

Çetinkaya F and Bekleyen A 2017, Spatial and temporal distribution of aquatic insects in the Dicle (Tigris) River Basin,Turkey, with new records. *Turkish Journal of Zoology* 41: 102-112, http://dx.doi.org/ 10.3906/zoo-1512-56.

Che Salmah M R, Al-Shami SA, Madziatul Rosemahanie M and Abu Hassan A 2013, Biological and ecological diversity of aquatic macroinvertebrates in response to hydrological and physicochemical parameters in tropical forest streams of Gunung Tebu, Malaysia: Implications for ecohydrological assessment. *Ecohydrology,* 72: 496-507, http://dx. doi.org/10.1002/eco.1368.

Clarke, KR & Gorley, RNP 2006, PRIMER v6: User manual/tutorial. Plymouth, UK: PRIMER-E: Plymouth Marine Laboratory, 192p.

Deborde DDD, Hernandez MBM & Magbanua FS 2016, Benthic macroinvertebrate community as an indicator of stream health: The effects of land use on stream benthic macroinvertebrates. *Science Diliman* 28: 5-26.

Flotemersch, JF, Saavedra, JM, Laffitte, L, Laurenzano, B, Bonardi, MA & Blocksom, KA 2017, Benthic macroinvertebrate field sampling effort required to produce a sample adequate for the assessment of rivers and streams of Neuquén Province, Argentina. *Limnologica* 65: 55-60, http://dx. doi.org/10.1016/j.limno.2017.05.004

Foomani, A, Gholizadeh, M, Harsij, M & Salavatian, SM 2019, Spatial and temporal variations in benthic macroinvertebrates communities Shanbeh-bazar waterway, Anzali wetland leading to the Caspian Sea. *Iranian Journal of Aquatic Ecology,* 8: 87-95.

Gholizadeh, M 2021, Effects of floods on macroinvertebrate communities in the Zarin Gol River of northern Iran: implications for water quality monitoring and biological assessment. *Ecological Processes,* 10: 1-11, https://doi.org/10.1186/s13717-021-00318-0

Gholizadeh, M & Alinejad, M 2018, Assessment of spatial variability of some affecting parameters on water quality of Zarin Gol River in Golestan province. *Iranian Journal Environmental Science* 16: 111-126.

Gholizadeh, M & Heydarzadeh, M 2019, Functional feeding groups of macroinvertebrates and their relationship with environmental parameters (Case study: Zarin-Gol River). *Iranian Journal of Fisheries Sciences* 19:

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 523~533
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2532-2543, http://dx.doi.org/10.22092/IJFS.2019.118132

Gholizadeh, M & Boveiri, S 2019, The investigation of macroinvertebrates abundance in the Zarin-Gol River (Golestan province). *Journal of Experimental Animal Biology* 7: 89-100, http://dx.doi.org/ 10.30473/EAB.2018.5328.

Imanpour Namin J, Sharifinia M and Bozorgi Makraniet A. (2013). Assessment of fish farm effluents on macroinvertebrates based on biological indices in Tajan River (north Iran). *Caspian Journal of Environmental Sciences,* 11: 29-39.

Jun, YC, Kim, NY, Kwon ,SJ, Han, SC, Hwng, IC, Park, JH, Won, DH, Byun, MS, Kong, HY, Lee, JE & Hwang SJ 2011, Effects of land use on benthic macroinvertebrate communities: Comparison of two mountain streams in Korea. *Annales de Limnologie– International Journal of Limnology,* 47: S35-S49, http://dx. doi.org/10.1051/limn/2011018.

McCune, B, & Mefford MJ, 1999, PC-ORD, Multivariate analysis of ecological data, version 4.0. MjM Software Design, Gleneden Beach, Oregon, USA, 237 p.

Needham JG 1976, A guide to the study of freshwater biology. Holden Sanfrancisco, 107 p.

Nessimian, JL, Venticinque, EM, Zuanon, J, Marco, P, Gordo, M, Fidelis, L, Batista, DJ, & Juen L 2008, Land use, habitat integrity, and aquatic insect assemblages in Central Amazonian streams. *Hydrobiologia* 614: 117-131. http://dx.doi.org/10.1007/s10750-008-9441-x

Palmer, MA, Moglen, GE, Bockstael, NE, Brooks, S, Pizzuto, JE, Wiegand, C & VanNess, K 2002, The ecological consequences of changing land use for running waters with a case study of urbanizing watersheds in Maryland. *Yale Forestry and Environmental Sciences Bulletin,* 107: 85-113.

Ravanab Consulting Engineering Company 2005, Comprehensive plan of multipurpose forestry In watershed (Chehel Chai). Organization of Forests, Rangelands and Watersheds of Iran, Department of Natural Resources of Golestan Province, Iran, 105 p.

Rosenberg, DM & Resh VH 1993, Fresh water bio-monitoring and benthic macroinvertebrates. New York: Chappman and Hall, 488 p.

Sharifinia, M, Imanpour Namin, J & Bozorgi Makraniet, A 2012, Benthic Macroinvertabrate distribution in Tajan River using Canonical Correspondence Analysis. *Caspian Journal of Environmental Sciences,* 10: 181-194.

Thorp, JH & Covich, AP 2010, Ecology and classification of North American freshwater invertebrates. Burlington, MA: Academic Press (Elsevier), 1021 p.

Van Ael, E, De Cooman, W, Blust, R & Bervoets, L 2015, Use of a macroinvertebrate based biotic index to estimate critical metal concentrations for good ecological water quality. *Chemosphere,* 119: 138-144. http://dx.doi.org/10.1016/j.chemosphere.2014.06.001.

Villeneuve, B, Piffady, J, Valette, L, Souchon, Y & Usseglio Polatera, P 2018, Direct and indirect effects of multiple stressors on stream invertebrates across watershed, reach and site scales: a structural equation modelling better informing on hydromorphological impacts. *Science of the Total Environment,* 612: 660-671, http://dx. doi.org/10.1016/j.scitotenv.2017.08.197.

Xiao-jun, W, Jian-yun, Z, Shahid, S, El-Mahdi, A, Rui-min, H, Zhen-xin, B & Ali M 2012, Water resources management strategy for adaptation to droughts in China. *Mitigation and Adaptation Strategies for Global Change,* 17: 923-937, http://dx. doi.org/10.1007/s11027-011-9352-4.

Zintzen, V, Norro A, Massin, C & Mallefet, J 2008, Spatial variability of epifaunal communities from artificial habitat: shipwrecks in the Southern Bight of the North Sea. *Estuarine, Coastal and Shelf Science* 76: 327-344, http://dx. doi.org/10.1016/j.ecss.2007.07.012.

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