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Original article

The use of multi metric index for pollution tracing by use of geographic information system

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A R T I C L E I N F O

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A B S T R A C T

Aquatic organisms are used extensively in water quality assessment and ecosystem health quantity scale in streams. Mohammad-Abad creek (Golestan Province) is accounting one of the tributary streams of Gorgan-Rood River. In this study, 21 sites were selected along 25 kilometer of stream long according to ingredient pollutants. Sampling took place each 45 days. After segregation and identification of samples, biological indicators (Hillsenhof and MMIF) are used for water quality assessment. Also Multi Metric index are used in Geographic Information System (GIS) area that comprises 5 metric indices. By this way we could compare environmental effects with anthropogenic ones. Results showed that downstream sites had high organic pollution loading. Studied sites in summer, autumn and winter had high water quality level whereas most of sites in spring placed on good level quality. Assessments showed that biological indicators just identify organic pollution traces but multi metric indices can demonstrate both organic pollutions and environmental effects. Totally, use of HFBI and MMIF indices together would be worthy because they are complement of each other in stream ecological assessment.

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1. Introduction

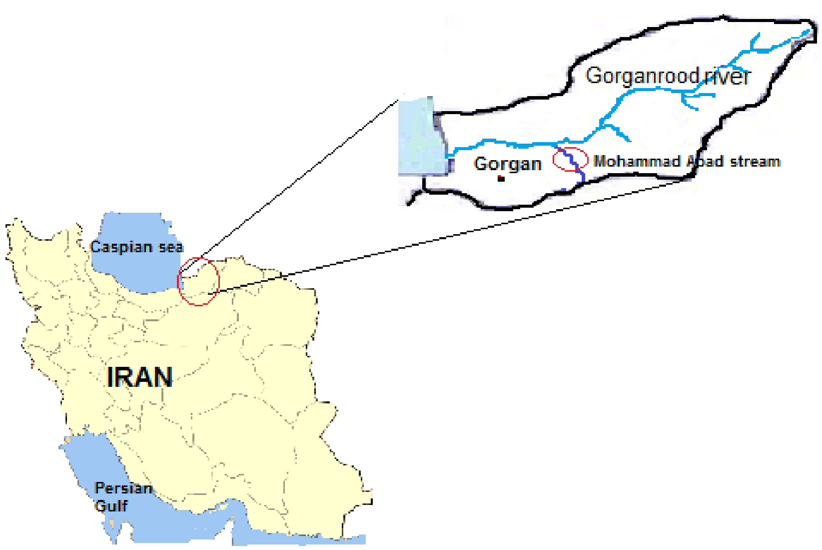
The use of benthic macroinvertebrate fauna as an indicator for a qualitative classification of freshwater systems has increased in many regions of the world within the last years (Blocksom and Johnson, 2009; Fausch, et al., 1984). One of the major advantages of bio-monitoring with benthic macroinvertebrates is the possibility to detect changes in water quality that occur at the time of sampling as well as changes that have occurred within a longer period before sampling, due to the relatively sedentary life style and long life spans of these organisms (Rosenberg et al. 2004; Gabriels et al. 2006; Barry et al. 2009; Bohmer et al. 2004).

Early 20th century scientists used simple single-parameter techniques (such as the European Saprobic Indices for organic pollution) but limitations were quickly discovered and, as aquatic communities faced an increasingly abundant and diverse set of anthropogenic disturbances, this methodology was replaced in the 1980s with broader concepts such as the multimetric approach. Multimetric indices were conceived as a way to quantify Frey's (1977) concept of biological integrity, e.g. Karr's (1981) Index of Biotic Integrity (IBI). This method requires aggregation of multiple ranked biological assemblage data metrics to produce a single unites index value of freshwater conditions and overall stream quality (Karr *et al*., 1986).

Complex ecological systems and broad human impacts on aquatic communities require measurements that integrate multiple factors. These multiple factors incorporate measurements at the individual, community, and landscape scales. Individual measurements, termed metrics, may include those derived from structural aspects of communities (e.g. species composition and abundance), functional characteristics (e.g. feeding habits and life history), and measures of condition (e.g. presence or absence of tolerant organisms and individual health). Multi-metric indices are composed of ecologically sound measurements that have known responses to anthropogenic disturbances. All metrics have an ecological response deviance when measured on range of environmental conditions. When metrics are organized and selected systematically within a regional framework, multi-metric indices measure changes along disturbance gradients (Karr and Chu, 1997).

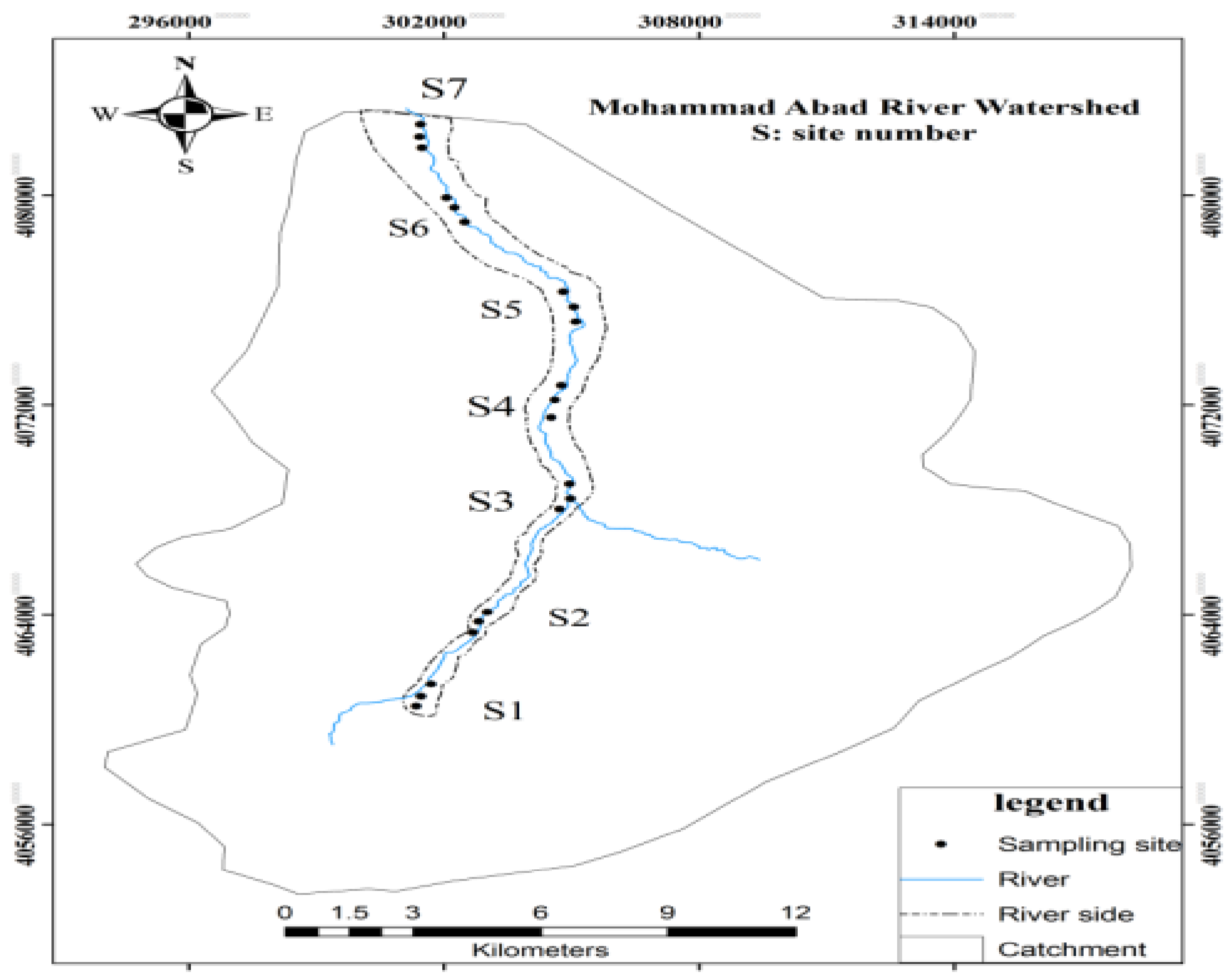
2. Materials and methods

Fazel-Abad area is located 35km far from Gorgan city (capital of Golestan Province) and Mohammad-Abad Stream, with 25km length, in this area play important role both agriculture and human consumptions.



Map1. Mohammad Abad stream location in Golestan province, Iran.

Benthic macroinvertebrates sampling occurred with standard Surber sampler (30cm×30cm), every 45 days in 2009 according to Robinson and Uehlinger (2001). According to pollutant ingredients like direct rural, ranch and gravel activities sewage loading and the pointes mentioned by Voelker and Renn (2000), 7 sample and 21 subsample sites were selected. Sampling performed almost all aquatic habitats such as bed surface (gravel, silt and mud), macrophyta and artificial habitats. All collected materials tested form invertebrates existence. Identification occurred according to taxa level described by (Nafisi and Ahmadi, 2000).



Map 2. Mohammad Abad River watershed and selected sites.

Primitive indices were selected based on effectiveness from taxa richness and ratio of sensitive to taxa resistance. Finally five metric indices were selected according to Gabriels *et al.* (2010), the value of each index divided into five levels. Metric indices that are used in this multi metric index consist of taxa richness (TAX), number of *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT), number of sensitive families to pollution except EPT (NST), Shannon-Winner index (SWD) and the mean of pollution grades of all taxa (MTS) base on EU's water bodies assessment framework (EU, 2000).

All metric indices classified into four levels between "0 to 4" degree. Zero score for each index describe bad status and the score of 4 describing good ecological status. Finally these scores added together_and divided to 20 then. Result is a number between 0 to 1 and showing the bad and good ecological status, respectively (table 2). So MMIF is a reasonable scale for ecological assessing of streams.

Table1
Metric indices and their values used in MMIF.

Metrics	MMIF score				
	MTS	SWD	NST	EPT	TAX
0	≤2	≤ 0.2	0	0	≤5
1	≤3.125	≤1.025	≤ 2.25	≤ 1.75	≤ 12.5
2	≤ 4.25	≤ 1.8	≤4.5	≤ 3.5	≤ 19.5
3	≤5.375	≤2.67	≤ 6.75	≤ 5.25	≤ 26.75
4	>5.375	>2.67	>6.75	>5.25	>26.75

Table 2
Ecological conditions for MMIF base on their values.

Ecological Condition	MMIF value
High	0.9 – 1
Good	0.7-0.89
Moderate	0.5-0.69
Poor	0.3-0.49
Bad	0-0.29

According to capability of geographic information system (GIS) in assessing of ecological status of water bodies specially streams and their catchments, we used GIS for better assessing of stream. All data was divided to three sectors including biological (such as kinds of taxa and their numbers), physical and chemical data of water (like temperature, salinity and pH) and finally hydrology regime (such as width of river, thalweg line). All of this data introduced to computer in Excel program. By use of hydrology regime of stream, which took during sampling, topographic maps (1:25000) and points of stations, which located with GPS set, location of Mohammad-Abad Stream introduced to GIS area. To reach MMIF in GIS, first all of five indices extended to surface of stream by use of Kriging function in GIS according to Excel data. So Raster map was generated for each index. This process occurred separately for each sampling and achieved 8 maps for them. The mean of season maps counted with Overlay function, so output Raster is the annual map of MMIF index. Process model of MMIF counting in GIS area is illustrated on diagram 1.

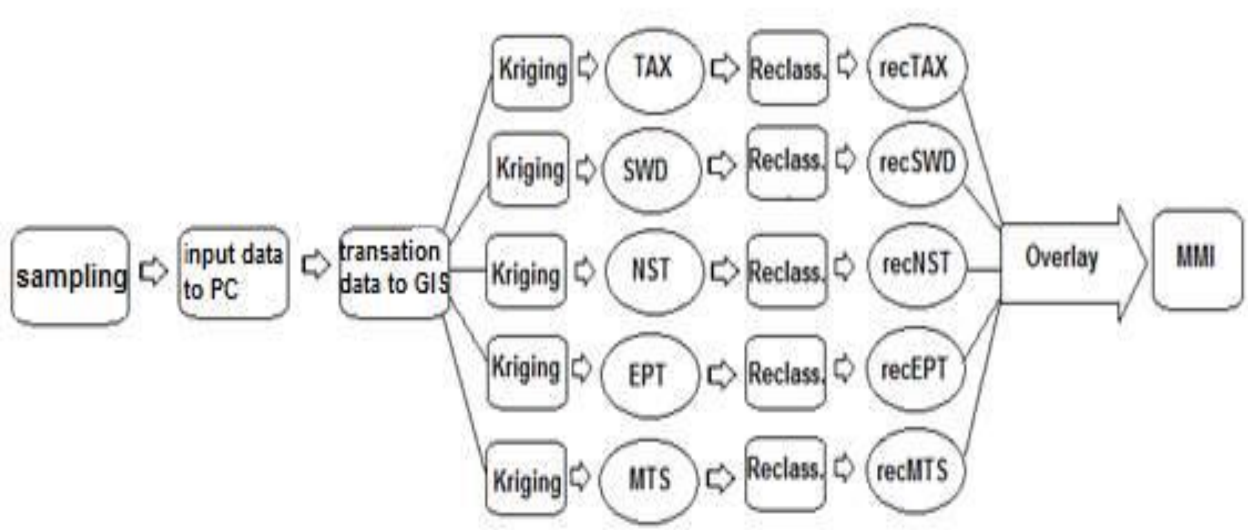
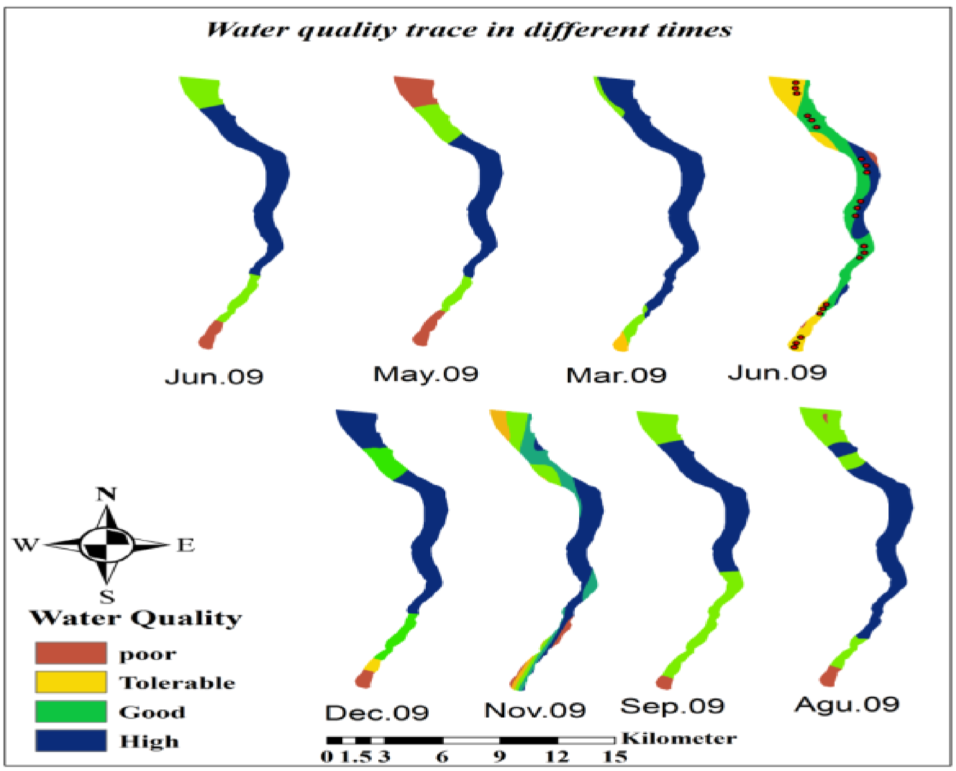


Diagram 1. GIS processing model for counting MMIF index.

3. Results

During 8 sampling in 2009, 74000 macro invertebrates were identified which were belonging to 5 order and 16 taxa. Minimum and maximum of macro invertebrate distribution were 4716 (state 5 in summer) and 113 (state 1 in autumn), respectively. Maximum frequency almost on the all sites belonged to *Ephemeroptra*. 6 spices from four taxa of *Ephemeroptera* identified that *Baties* spices comprised maximum distribution. Second order was *Diptera* which after *Ephemeroptera* had most distribution in all sites. 5 taxa were identified from this order which *Simulidae* and *Chironomidae* comprised most richness and most of 78 percent of all this order. In *Trichoptera* order only two spices from two taxa identified that consist of *Hydropsychidae* and *Glossomatidae*. Also identified spices from *Plecoptra* order in some stations (3, 4, 5 and 6) had most distribution rather than other orders. Finally from *Coloptera* order only one spices of *Elmidae* was identified that it was observed in 3, 4 and 5 states.

According to rendered GIS frame and model for MMIF index, for each sampling one map and from overlaying this maps acquired an annual map. Surveying of spring (May and Jun.) maps indicates ecological status and organic pollution condition in major stations have high quality status (map3). Also stations 1 and 7 had poor status in this time. Summer map of MMIF has similar status to spring so that ecological impacts observing on station 7, too. Other stations were located on good and high quality. Pollution was observed after site no.4, too. Whereas even some sectors of this station had bad condition (map....)



Map 3. Water quality trace in different month.

In addition, site 7 had medium to bad level quality attribute in autumn; meanwhile this site had same status with other seasons. Another stations had high to good levels. MMIF index scale in winter was a little different from other seasons. Most of stations in this term had high level and only station 1 and partial of station2 had tolerable and good levels, respectively (map.....).

Hilsenhoff index (Hilsenhoff, 1988) is other metric indices which pollution procedure can be estimated with this index. In this article, we used Hilsenhoff Family Biotic Index to assessing accuracy of MMIF index. HFBI values were separately accounted for each site. HFBI values had ranges between 1.3 to 5.03 degrees in different stations. Base on HFBI organic pollution levels, water quality in different stations segmented to high, very good, good and tolerable. As site no. 3 in autumn placed on good level and another sites placed to high level because the values of this index in mentioned sites were below of 3.75. Also in winter water quality segregated in high and very good levels so that all sites placed on high level quality except site 7 that placed on good level (map1).

Results show that studied sites in summer, autumn and winter had high water quality level whereas most of sites in spring placed on good level quality. In summer, spring and winter site 7 had lowest level of quality and lowest water quality observed in site no. 7 in spring.

4. Discussion

According to MMIF, which consist of five metric indexes, can showing the stream ecological status. In this index, quality condition of sites counted according to environment impacts (such as water temperature or river bed) and organic pollution aspects (ratio of sensitive to resistance spices).

Output data of spring characterized good quality condition for most points of Mohammad-Abad Stream and only sites number 1 and 7 placed on medium quality status. Main cause of site no.1 level decline (which observed in another seasons too) is environmental bad condition. Significant of this condition include stability of bed surface and vegetation cover which site no.1 compare to downstream sites had poor condition. In the other hand, the MMIF values of site no. 7 were similar to site no.1 in all seasons. But the main reason of MMIF's value decrease was due to organic waste and sand production activities (anthropogenic effect). Also Hilsenhoff index prove existence of organic pollution in site no. 7. Sand and gravel industry activities before site 7 also caused temperature change and riverbed disturbing.

Summer maps of MMIF showing that results of MMIF index is compatible with Hilsenhoff values. This compatibility observed in other seasons by this difference that site no.1 in all HFBI's maps was not polluted site. Hence, assessing of organic pollution with HFBI index has proficiency than MMIF, but MMIF is very spacious and separate various biotic and abiotic conditions so it is better for ecological impacts. Therefore use of these indices (HFBI and MMIF) together is worthy because they are complement of each other in stream ecological assessment.

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