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Evaluation of bio-indicators of river Haji Abad using aquatic insects fauna

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Abstract

The present research was conducted to investigate benthos communities and their population structure in River Haji Abad located in the west of Hormozgan province during October 2012 to September 2013. In total, three study stations were determined based on the region's topography and taking triplicate samples at each station, its macrobenthos fauna was sampled monthly using 500 micron Surber sampler. Using formalin 4%, samples were fixed and isolated, identified and counted in the laboratory of Azad University, Bandar Abbas branch. In total, 5 classes, 9 orders and 24 families were identified, where aquatic insects' larvae had the highest diversity and abundance among the samples. Individuals belonging to the two orders of Diptera and Ephemeroptera were dominant in all the three stations. The maximum abundance of all organisms in this period was 4195 per sq.m in station 3 and the minimum was 2935 per sq.m in station 1. The data related to macrobenthos were summarized as community structure metrics including EPT index (Ephemeroptera, Plecoptera, Trichoptera) and the ratio of the abundance of EPT to Chironomidae family. In addition, Shannon Wiener diversity index and Bauer bio indicator were also investigated and calculated in the stations. Station 2 has had the highest diversity of species from Shannon Wiener diversity index viewpoint. From Bauer index viewpoint, station 2 has also had the least pollution during the year in comparison with the other two stations.

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Introduction

Rivers are the natural habitat for many species of aquatics, each of which with its own fauna and flora. Nowadays, construction of buildings and structures such as dams and bridges without considering environmental rules, sand operation and wastewater discharge (agricultural, industrial, and domestic and etc.) are regarded as factors influencing the change and reduction of the quality of these valuable ecosystems such that biological communities face limitation in many polluted rivers and their resources such as native fishes, algae, benthic invertebrates and other living communities are facing extinction (Malaysia Convention on Biological Diversity, 2004).

According to Rosenberg, 1999 benthic invertebrates living in streams and rivers are regarded as the most important aquatic resources, which play a major role in the food network and products of rivers. In addition, these organisms are used to determine the environmental quality of the rivers and biologically monitor them. In this regard, indicator organisms and their reactions to environmental conditions are considered. Generally, researchers presume the measurement of physical and chemical parameters of water such as photography and biological investigation (especially for macrobenthos) as taking video of an ecosystem (Rosenberg, 1999). In fact, the only practical and economic way to determine the ecological health of waters and whether human activities result in the reduction of their quality or not, is the biological evaluation and monitoring (Lenat, 1993).

The main idea of the monitoring is quite simple because various kinds of fauna of streams are able to survive under definite conditions of water quality. When conditions change; for example when a river receives huge amount of pollution, abundance, distribution and composition of population of aquatic organisms in the affected region is changed. Although fishes and algae have also application in environmental monitoring plans, benthic invertebrates are regarded as the most common organisms used in this area. The interesting point is that the number of environmental indices defined based on benthic invertebrate communities is approximately five times the total indices for other groups (algae and fishes). In addition, benthic invertebrates are amongst the most fundamental biological components of rivers and using their population's composition and relying on indicator groups, qualitative conditions of rivers can be determined (Reynoldson, 1992).

Several features cause these organisms to be paid attention more by experts of aquatic ecosystems. Following items can be mentioned among these features.

1- All are present in basins. 2- They have high species diversity and with a lot of species have often a widespread range of sensitivity to pollutants, which will create extensive responses to change of conditions. 3- They live in bed and don't have any notable displacements or movements. 4- They have a long life cycle such that they make it possible to investigate and determine the location and time limits and extent of turbulence. 5- Unlike the measurement of physical and chemical parameters, they display qualitative changes of water periodically (Feminella, 1996). All these are regarded as the advantages of benthic invertebrates for biological evaluation studies. The assumption behind using benthic invertebrates is that streams and rivers under the pressure of pollution, where resistant species are dominant, have less diversity (Wallen, 2002). The importance of biological studies of flowing waters and determination of qualitative condition of water is more clarified by the mentioned explanations. Taking into consideration the fact that identification of aquatic organisms of an aquatic ecosystem and determination of their role in the evaluation of water quality is necessary to find out about its stability, the present research aims at identification of macrobenthos of River Haji Abad and their distribution and sensitivity to the qualitative conditions of water in various seasons of the year.

Materials and methods

Description of Study Area

The investigation was conducted on River Haji Abad (Abgoldoon) in Hormozgan province for one year during October 2012 to September 2013 and in a distance of about 60 km. Three study stations (table 1) were selected along the above mentioned route based on the specific conditions of the river (height above the sea level, water velocity, bed genus, natural and artificial factors) and the region's topography.

Table 1. Sampling stations specification.

station name	northern longitude	eastern latitude	height above sea level	distance between two stations
inside Haji Abad town the bridge	28° 18' 420"	55° 53' 999"	923 m	-
outside Haji Abad town	28° 17' 711"	55° 53' 650"	891 m	4 km
after palm-groves	28° 16' 706"	55° 52' 500"	860 m	8 km

Sampling of Aquatic Insects

Sampling was conducted in triplicate each time. Various stations were sampled monthly using Surber device with a 500 micron mesh (dimensions of Surber sampling device 30 by 30 cm). Samples were fixed with 4% formalin and were transferred to the laboratory for investigation and identification.

Processing, Preservation and Identification of Insect Specimens

In the laboratory, using a 400 micron sieve, samples were separated from the sampling container and were put in a plate. Then isolation was performed under the loop. Identification keys were used to identify benthos (Ahmadi and Nafisi, 2000). Using Malaysia made portable device AZ 8685, AZ 8585, factors of water temperature (C), EC (electrical conduction) and pH were measured three times a month. Height above sea level was measured with GPS device with an accuracy of one meter.

Data analysis

The data obtained were calculated for various stations as community metrics including EPT abundance, % EPT, ratio of EPT abundance to Chironomidae, Bauer bio-indicators and Shannon diversity index (H'). In order to investigate the biological diversity, Shannon's formula (H') was used (Wilhm and Land Dorris, 1968).

$$H' = \sum_{i=1}^{S} \frac{Ni}{N} Ln \frac{Ni}{N}$$

In this equation, H' is the species diversity index, N the total number of individuals population, N_i the number of ith species and S the total number of species. The biological evaluation of the river and the biological index evaluation of the river was conducted using Bauer method and the following formula (Bauer, 1980):

$$Z = \frac{\Sigma O + 2\Sigma B + 3\Sigma \alpha + 4\Sigma P}{\Sigma N}$$

Z= biological situation

ΣN= abundance category

ΣO= category of Oligasaproby creatures

ΣB= category of β-Mesosaproby creatures

Σα= category of α-Mesosaproby creatures

ΣP= category of Polysaproby creatures

The obtained results were categorized according to table 2.

Table 2. Categorization of classification of water quality based on biological situation by Bauer method.

biological situation	qualitative class
1-1.5	I=Oligasaproby (low pollution zone)
1.5-2.5	II=β-Mesosaproby (average pollution zone)
2.5-3.5	III=α-Mesosaproby (severe pollution zone))
3.5-4	IV=Polysaproby (the most severely polluted zone)

Results

In total, during the study and sampling of benthos fauna of River Haji Abad in the study area, 5 classes,

9 orders and 24 families were identified, the major part of which consisted of aquatic insects larvae (table 3). In average, the maximum and minimum abundance of benthos was obtained as 4195 and 2935 per sq.m in stations 3 and 1 respectively (Fig. 1). From Diptera order, as the most diverse and biggest order of aquatic insects, two families of Chironomidae and Tipulidae were identified, and in total, the abundance of the above mentioned order was 33% and was dominant in all three stations (table 3 and Fig. 2).

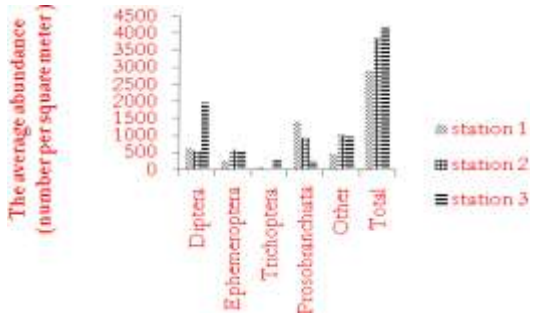

Fig. 1. Average abundance of various groups of benthos (number per square meter) in study stations of River Haji Abad (2012-2013).

After Diptera order, Prosobranchiata order had the highest number with 27% abundance. Three families of Hydrobiidae, Valvatidae and Physidae were identified among the order (table 3 and Fig. 2). After the above mentioned two groups, the Ephemeroptera order was put in the third place with 21% abundance. Three families of Baetidae, Leptophlebiidae and Caenidae were identified among the order (table 3 and Fig. 2). The other important order was the order of Trichoptera with 5% abundance, among which families of Hydroptilidae and Hydropsychidae were identified (table 3 and Fig. 2).

Among other aquatic insects identified in the study stations of River Haji Abad, orders of Collembula, Coleoptera, Hemiptera and Odonata can be named (table 3). In addition, among crustaceans Amphipoda order, Gamaridae family *Gammaruspulex* genus, among Archnidae class Hydracarina order, Limnocharidae family and also among Oligochaeta the two families of Naididae and Tubificidae can be named (table 3).

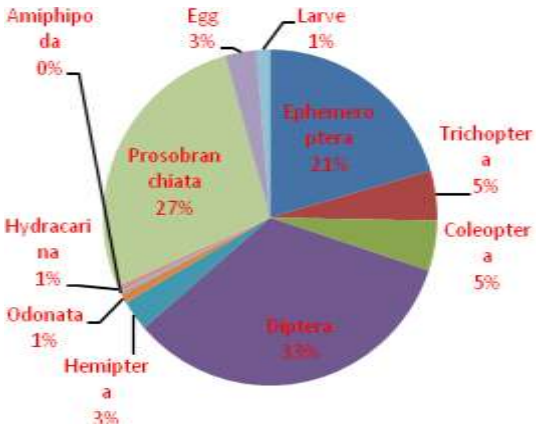

Fig. 2. Abundance percentage of all macrobenthos during the sampling period of River Haji Abad, Hormozgan province (2012-2013).

Table 3. Various groups of benthic invertebrates identified in River Haji Abad stations studied.

Order	Family	*Genus*
Ephemeroptera	Caenidae	*Caenis* sp.
	Leptophlebiidae	*Habrophlebiafusca*
	Baetidae	*Baetis* sp.
Trichoptera	Hydroptilidae	*Hydroptilasparsa*
	Hydropsychidae	
Coleoptera	Elmidae	
	Dytiscidae	*Llybiuserichson*
	Gyrinidae	
Diptera	Chironomidae	
	Tipulidae	
Hemiptera	Mesoveliidae	
	Corixidae	
	Corixidae	*Micronectapoweri*
	Gerridae	*Amemboahorvathi*
Odonata	Cordulegasteridae	*Codulegasterboltonii*
	Gomphidae	

Order	Family	*Genus*
collembola		
Amiphipoda	Gamaridae	*Gammaruspulex*
Hydracarina	Limonocharidae	
Prosobranchiata	Hydrobiidae Valvatidae Physidae	*Panorbis*sp.
	sphaeriidae	*Sphariums*p.
Olig	Naididae	
ocheata		
	Tubificidae	

The richness percentage of EPT is the abundance percentage of all the identified species belonging to orders Trichoptera, Plecoptera and Ephemeroptera, which are in fact considered as the orders sensitive to pollution and the existence of these benthos in the river indicates the favorable condition of the river. As it is seen in Fig. 3, the maximum percentage of EPT abundance is related to September and station 3 with the abundance percentage of 62.71 while the least abundance percentage is related to February and station 1 with the abundance percentage of 4.97. However, station 2 has had the best general condition from this perspective.

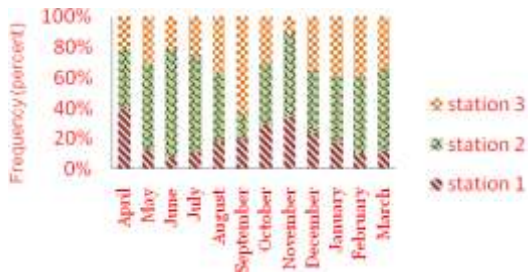

Fig. 3. Richness percentage of EPT in various stations and months of the year in River Haji Abad, Hormozgan province. Hormozgan province.

The ratio of the abundance of EPT to Chironomidae is the ratio of the abundance of total individuals belonging to the order of Trichoptera, Plecoptera and Ephemeroptera to the abundance of all individuals of the Chironomidae family. The ratio of sum of the abundance of EPT families to Chironomidae has been shown in Fig. 4 for various months and stations. As it is seen in the Fig. the highest abundance of EPT/CHIR is related to station 3 with the value of 9.25 and the least Fig. is related to station 1 with the value of 0.098 in June.

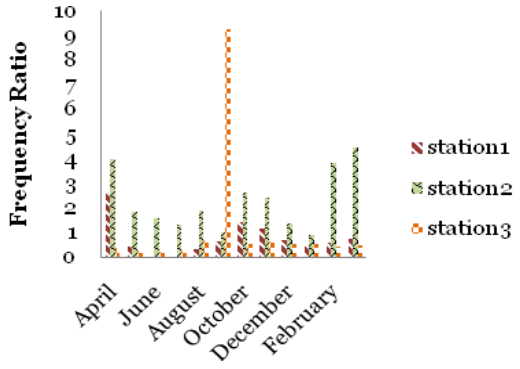

Fig. 4. Ratio of abundance of EPT to Chironomidae in various stations and months of the year in River Haji Abad, Hormozgan province.

From Shannon diversity index viewpoint, the highest amount of the index was seen in station 2 in February as 3.424 while the lowest value was seen in station 1 in August as 1.996. Generally, station 2 has had the most diversity of species and better conditions with respect to stations 3 and 1 (Fig. 5).

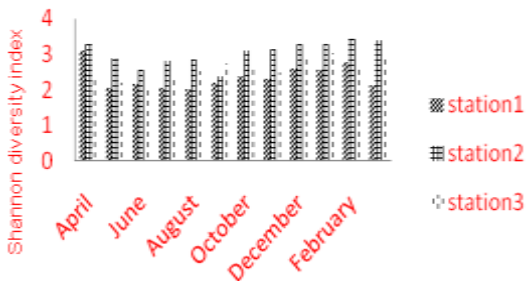

Fig. 5. Shannon diversity index in various stations and months of the year in River Haji Abad, Hormozgan province.

From Bauer bio-indicator viewpoint, the highest amount related to station 1 was recorded in June (2.36), while the lowest value related to station 2 was recorded in April (1.05). Station 2 had the low levels of pollution in all months of the year, while pollution of stations 1 and 3 oscillated during the year (Fig. 6).

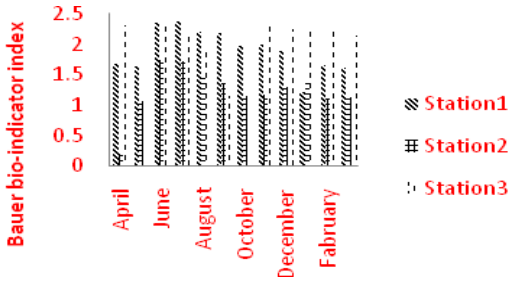

Fig. 6. Bauer bio-indicator index in various stations and months of the year in River Haji Abad, Hormozgan province.

Discussion

The low variability of aquatic insect fauna in Haji Abad river suggested that biotic indices at the family level may overestimate water quality more than those based on species taxonomic level because family taxonomic level usually use intermediate species tolerance values. Lenat and Resh (2001) also suggested that the family taxonomic level may be adequate in terms of cost efficiency, especially when few taxonomic experts are available. The significant variation of the total number of aquatic insect assemblages collected from 3 stations could be modulated by their different levels of sensitivity to pollution, together with many other physical and chemical factors in the water body ecosystem. Human activities might change the normal development of these river, especially at the fish aqua culture. Human activities, such as recreational and agricultural activities were associated with a reduction in species diversity of aquatic insect communities (Wahizatul *et al.*, 2011). In addition, physical and chemical disturbance, seasonal water flow, temperature, ion concentrations, food base of the stream, interaction with the river biota and substrate were also major factors in determining the composition and abundance of aquatic insects (Ward and Stanford, 2000).

The abundance of Ephemeroptera, Plecoptera, Trichoptera and Chironomidae indicates the balance of community, since Ephemeroptera, Plecoptera and Trichoptera are particularly sensitive to water quality and Chironomidae less sensitive to environmental stress (Popoola and Otalekor, 2011; Devi *et al.*, 2013). An aquatic community considered to be good if biotic conditions will display an even distribution among these four insect families, while aquatic community with disproportionately high number of Chironomidae may indicate environmental stress (Lenat and Penrose, 1996). Nymphs and larvae of Ephemeroptera, Plecoptera and Trichoptera were considered integral item of the undisturbed rivers (Sporka *et al.*, 2006).

The ratio of the abundance of EPT to Chironomidae

In general, the highest environmental stress of station 1 was related to June in spring, while station 2 had the lowest levels of environmental stress in all three sampling months of spring. In summer, the highest environmental stress was related to station 1, which indicates a high environmental stress in the station. The least level of environmental stress was measured in station 3 in September. However, station 2 had a more favorable condition in the other two months of the season.

In autumn, the highest and lowest level of environmental stress was related to station 3 and 2 respectively, with no significant difference. In winter, generally station 2 had more favorable conditions with respect to stations 1 and 3 and the severity of the environmental stress in stations 3 and 1 were more.

However, generally the unusual increases in the number of Chironomidae with respect to the organisms of sensitive groups of EPT, which leads to the decrease of the ratio of the abundance of EPT to Chironomidae, is an indicator of the environmental stress (Barbour *et al.*, 1998). The quantity and quality

organic materials entering the river as a result of activities of fish breeding farms or domestic wastewater may impact the energy structure and communities of benthic invertebrates and in this way cause some disturbances in the ecosystem operation because the ratio of EPT to Chironomidae is reduced and filtering groups increase in the areas with high loading of organic materials (Rosenberg, 2004). Therefore results obtained in this study are in conformity with the results of the study of Loch and *et al.*, (1999), Rosenberg and Resh (1993) and Ghane Sasansaraei and *et al.*, (2006) and also Shomali and Abdolmaleki (1996).

Results obtained show that station 1 with the lowest value of the ratio (0.098) in June has had the highest level of environmental stress and station 3 with the highest value of the ratio (9.25) in September has had the lower level of environmental stress. In total it can be concluded that in comparison with the other two stations, station 2 had better conditions and faced less environmental stresses. Therefore, in order to justify the obtained results with respect to the above studies results, it can be said that as a result of entry of urban and agricultural wastewater with high organic materials loading, the ratio of EPT to CHIR is reduced while in station 2 water doesn't have much oscillations and have more favorable conditions as a result of being far from the city and self refining.

In station 3 also organic materials loading has been high as a result of existence of palm groves and agricultural wastewater and the reason of increase of the ratio of abundance of EPT to Chironomidae in station 3 in September can be attributed to the reduction of organic materials load and also vertical immigration of Chironomidae family members from bed to the surface. The present findings were in agreement with those of Paparisto *et al.,* (2010) who calculated EPT Biotic index for 4 stations at Shkumbni river in Albania and observed change of classification of water quality.

Shannon diversity index

Applications of community diversity indices for the monitoring of water quality are based on the assumption that the structure of benthic communities changes with the environmental disturbances because some species are pressured more than the others (Taylor, 2000). One of the most common diversity indices is the Shannon Wiener index. Based on the Shannon Wiener index, the less the index and the closer to zero, the environment is more polluted. In addition, the increase of the index to more than 3 indicates no pollution of the water resource (Wilhm and Dorris, 1968; Lenat, 1993). Generally, the highest value of the Shannon Wiener index (H') was related to station 2 in February with the amount measured as 3.424 and the minimum value was related to station 1 in August. Since there is correlation between diversity, stability and resistibility of ecosystem against disturbances, calculation of the diversity index for benthic invertebrate species is an estimation of an essential aspect of an ecosystem structure to gain a direct insight into the biological health of the system (Whashington, 1984).

In total, the evaluation of stations with respect to the Shannon diversity index in various seasons showed that the best situation is related to station 2 in February and the worst situation is related to station 1 in August, which is relatively polluted. In addition, the least species diversity was evaluated for station 1 in August and the highest species diversity was related to station 2 in February. The obtained results are consistent with those of Hynes (1998), Lenat (1988) and Leunda and *et al.,* (2009).

Bauer index

Using Bauer method, flowing waters can be divided into four classes with respect to the entering organic material load and pollution according to table 1. Survey of sampling stations showed that highest values of the index was related to station 1 in June with the value of 2.36 and the least value was related to station 2 in April with the value of 1.05. Based on table 1 it can be concluded that in station 1, in June,

water is among the qualitative class II with the average pollution and station 2's water in April is among the qualitative class I with low pollution. From biological point of view, the water of River Haji Abad can be categorized in the qualitative class of I and II. Therefore the water is suitable for breeding aquatics. It should be noted that three species of carp fishes of fresh water live in the river. However, due to low volume of the river water as a result of consecutive droughts and spoilage of water paths, the river water cannot be used for extensive breeding of aquatics.

Conclusions

In general, organisms, which are most sensitive to pollution, such as Coleoptera and Trichoptera as utilized in this study, were relatively poor in stations 1 and 3. Thus, the density of the families of the Ephemeroptera group in stations 1 and 3. Dropped when compared with that at station 2. One peculiar observation is that some of the insects like Ephemeroptera prefer slow running water environment with macrophytes, which support their ecology. We strongly advocate that organic farming should be encouraged and practiced as run-off from agricultural sites contains lots of contaminants; and washing of all kinds and channeling of industrial effluence be discouraged. Nomadic agriculture should be restricted to designated sections along the rivers catchment. The need for long-term hydrobiological investigation, with elaborate emphasis on water quality monitoring and the ecology of macrobenthic fauna is so much recommended for the safety and conservative use of our fresh water bodies and the resources.

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