Available Online at http://www.recentscientific.com

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 6, Issue,1, pp.2477-2484, January, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

A COMPARISON OF FRESHWATER MACROINVERTEBRATES COMMUNITIES IN WADI AL-ARJ, TAIF, KINGDOM OF SAUDI ARABIA

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ARTICLE INFO

Article History:

Received 2nd, December, 2014
Received in revised form 10th, December, 2014
Accepted 4th, January, 2015
Published online 28th, January, 2015

Key words:

Macro invertebrates, Seasonal changes, Environmental factors, Stream, Habitat structure.

ABSTRACT

Macro invertebrates are most commonly used for biological monitoring of aquatic ecosystems. The present study aimed to evaluate changes of aquatic macro invertebrates community according to seasonal fluctuations and habitat structures at Wadi Al-Arj, Taif, Kingdom of Saudi Arabia. Three sites have been chosen for study. Two samples were taken twice monthly along a period of one year, from the beginning of February 2012 to the end of February 2013. During the sampling period some environmental factors (air and water temperature, pH and TDS) were measured. Sites showed significant differences in water pH and the total dissolved salts (TDS). The composition of invertebrate community was 17 taxa in site II and site III while in site I was 20 taxa. Many of the collected invertebrates have significant differences among sites. The abundance of collected invertebrates has monthly variations. Statistical analyses showed no significant differences among sites in total abundance, taxa richness and Shannon diversity at the studied sites. It was noticed that these variables showed different patterns of monthly variations.

INTRODUCTION

During the present age there is an increase in the demand for water. The various sources of water has an important role in the functioning of the wheel of life, such as water, water underground dams and water valleys are an important source of irrigation human uses (Abueshey, 2012). Throughout the world and in the Kingdom of Saudi Arabia in particular, sewage water starts playing a crucial role in the management of water resource as an alternative for drinking water in agriculture. Shallow alluvium aquifers are the major source of groundwater in western Saudi Arabia. These aquifers are associated with major drainage systems (*Wadis*) collecting rainfall runoff and running from high lands toward either the Red Sea coast or the interior plains. The alluvium aquifers are believed to be prone to contamination from agricultural, industrial, and municipal activities (Al-Shaibani, 2008).

The downstream part of Wadi Wajj in Taif city, western Saudi Arabia represented by Wadi Al-Arj that flows from SW to NE through the city (Al-Shaibani, 2008). Raza, (2004) indicated that the Wadi Al-Arj aquifer is vulnerable to pollution. Part of Taif sewage system and storm runoff releases water just north of the city to wadi Al-Arj and waste products are dumped into the stream (Al-Shaibani 2008; Abueshey 2012).

Generally, in stream ecosystem research, invertebrates have a clumped distribution, which is assumed to be related to the mixture of interchanging environmental conditions in substratum (Townsend, 1989; Cortes *et al*., 2002). These conditions expected to change at scale of a few meters or centimeters. There are many factors such as current velocity, substratum particle size, stability and organic matter, regulating macroinvertebrate community structure at this small scale (Williams, 1980; Marchant *et al*., 1985; Williams and Moore, 1986; Arunachalam *et al.*, 1991; Malmqvist and Otto, 1987; Downes *et al.*, 1995; Gayraud and Philippe, 2001).

Macro invertebrates are the fauna most commonly used for biological monitoring of aquatic ecosystems worldwide. The most important advantages of using these fauna is that some have relatively long life span, they relatively sitting, have unreliable sensitivities to changes in water quality and they are easily to follow-up, however, that when assessing macro invertebrates, other physical, chemical and other biological data should be considered to support the water body assessment (Hellawell, 1986; Abel, 1989; Rosenberg and Resh 1993).

It is obvious that the composition and distribution of aquatic macro invertebrates in environment is governed by numerous abiotic and biotic factors which need to be taken into consideration in any research of stream macro invertebrates. Hella well (1986) concluded that during study the effect of factors effect on invertebrate communities there is a significant inter-habitat and inter-climatic variation differs among studies.

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Therefore, it is important to document factors associated with invertebrate diversity, for a variety of habitats and climates.

Information on the subject of freshwater invertebrate from the Arabian region is rare. Only some studies have examined the molluscs aquatic communities in the region (Victor and Al-Mahrouqi 1996; Roberts and Irving-Bell, 1997; Victor and Victor 1997), and aquatic taxonomy remains an area in need of considerable development (Walker and Pittaway, 1987; Boulton *et al*., 1992; Segars and Dumont, 1993; Schneider and Dumont, 1997; Magniez and Stock 1999; Martinez-Ansemil, *et al*., 2002).

Balian *et al*. (2008), highlight the lack of data from the Afrotropical (e.g. Southeast Asia) about biodiversity in freshwater ecosystems. The knowledge of freshwater fauna in the Arabian Peninsula is particularly limited (Victor and Al-Mahrouqi, 1996; Burt 2003; Abd El-Wakeil and Al-Thomali, 2013). Therefore, the present study aims to evaluate changes of aquatic macro invertebrates community according to seasonal fluctuations and habitat structures at Wadi Al-Arj, Taif, Kingdom of Saudi Arabia.

MATERIALS AND METHODS

The present study was performed at Wadi Al-Arg arj in Taif province, Kingdom of Saudi Arabia. Three sites at Wadi Al-Arj have been chosen for this study (Fig. 1). The sampling was carried out along a period of one year, from the beginning of February 2012 to the end of February 2013. Two samples were taken twice monthly from different two localities of each main site by time method (The process of collection took half an hour for each locality). The collected macroinvertebrate samples were transferred to the laboratory after put in perforated plastic boxes.

Figure 1 Maps showing the study sites at Wadi Al-Arj in Taif, Kingdom of Saudi Arabia

During sampling some environmental factors were measured, including air temperature (˚C), water temperature (˚C), Water pH and total dissolved salts (TDS) as ppm. In laboratory, the macro invertebrates were separated by hand picking and counted. The separated specimens were stored in plastic jars in 70% Ethanol before identified. Several published papers and keys were used to identify the collected invertebrates including; Walker (1959), Klemm (1972), Kalkman *et al*. (2008), Sawyer (1972), Neubert (1998), Ibrahim *et al*., (1999), Nesemann *et al*. (2011), Abd El-Aziz (2012) and Abd El-Wakeil *et al.* (2013). Invertebrates were identified to the lowest practical taxonomic level, species, genus and family levels. In addition to Identified specimens that are deposited in Educational Museum of Egyptian Fauna, Zoology Department, Faculty of Science, Assiut University, Egypt.

The present data was examined by Analysis of Variance on SPSS software package (version 17) (SYSTAT statistical program). In case of significant differences, the Duncan test was used on the same statistical package to detect the distinct variances between means.

RESULTS

Collecting sites description

Site I

This site is located as begin of the research area (North: 21˚ 19΄ 29.165΄΄, East: 40˚ 27΄ 38.661΄΄). It is surrounded by rocks. The bed and substrate of this site is muddy soil. The water depth ranges approximately from 30 cm to 45 cm. The dominate plants are *Acacia* sp., *Acacia laeta, Mentha longifolia, Ricinus communis, Xanthium strumarium, Lyceum shawii*, and *Pluchea dioscoridis*. The water of this site is directly and continuously exposed to waste of human activities (Fig. 2).

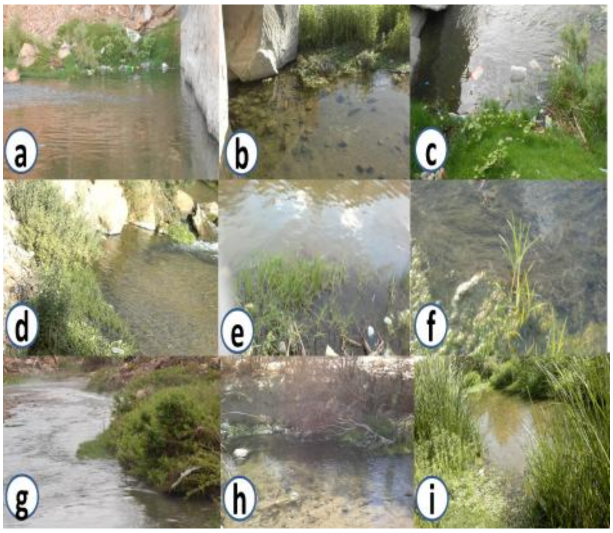

Figure 2 Photographs show studied sites in Wadi Al-Arj, Taif, Kingdom of Saudi Arabia. Site I: a,b,c; site II: d,e,f; site III: g,h,i.

Site II

This site is followed site I. It is approximately 7 meters for the location of the flow of the waterfall from the effects of nature (North: 21˚ 19΄ 27.634΄΄, East: 40˚ 27΄ 43.811΄΄). The bed and substrate of this site varies between clay soil, sandy soil and even gravel soil. The water depth ranges approximately from 25 cm to 40 cm. Cipridae fish, tadpole and frog were frequently observed. This site is surrounded by several plants. The dominant plant species including *Coronopus didymus, Chrozophora oblongifolia, Datura inoxia, Ricinus communis, Solanum incanum, Tamarix nilotica, Mentha longifolia,* , *Pluchea dioscoridis* and *Xanthium strumarium*. The water of this site is rich in filamentous algae (Fig. 2).

Site III

This site is followed site II (North: 21˚ 19΄ 27.922΄΄, East: 40˚ 27΄ 47.230΄΄). The bed and substrate of this site varies between clay and sandy soil. The water depth ranges approximately from 35 cm to 50 cm. Many tadpole in different size and frog were frequently observed. This site is surrounded by several grass and plants. The dominant plant species including *Acacia* spp., *Calotropis procera*, *Mentha longifolia*, *Pluchea dioscoridis*, *Ricinus communis* and *Xanthium strumarium*. The water of this site is suffer from pollution where large parts of water banks are pigmented black balloon and the stink function on pollution sewage and other pollutants (Fig. 2).

Environmental factors

Table (1) illustrated the means of environmental factors and the statistical differences between studied sites. It was shown that the differences between sites were significant in the case of water pH and the total dissolved salts (TDS), whereas the differences were non significant in the case of air and water the temperatures. The mean value of water pH of site I (8.1±0.5) was significantly different from those of site II (8.4±0.4) and site III (8.3±0.5). The mean values of total dissolved salts (TDS) at site I (460.1±72.3) significantly lower than site II (485.8±60.8) and site III (478.1±64.6).

observed invertebrate taxa were recorded in site I. *Haemopis grandis* was not observed in site II while *Basiaeschna* sp. nymph not recorded in site III. Other Two taxa; *Anax* sp. nymph and Gomphidae nymph were not recorded in site II and site III (Fig. 4).

Statistical result was shown that the differences among sites were significant ($p<0.05$) in the case of *Ambrysus* sp., Protoneuridae nymph, Cordulegastridae nymph, Corduliidae nymph *Pseudosuccinea columella*, *Physa acuta* and *Melanoides tuberculata*, whereas there was no significant difference in the density of the rest of the collected taxa (Fig. 4).

Seasonal variations of invertebrate taxa

The abundance of collected invertebrates has monthly variations. the statistical analyses these variations were significant in the case of *Ambrysus* sp., Coenagrionidae nymph, Protoneuridae nymph, Corduliidae nymph, *Libellula*

Table 1 Mean ± standard deviation (SD) of environmental factors for the study sites during the period of investigation (The similar characters for each factor show no significant difference).

Environmental factors	Site I		Site II		Site III		F	p value
Air temperature	21.9	± 4.8 **a**	21.8	± 6.5 **a**	21.7	± 7.9 **a**	0.017	0.983
Water temperature	22.7	± 1.6 **a**	23.0	± 2 **a**	22.7	± 2.2 **a**	1.231	0.297
Water pH	8.1	± .5 **b**	8.4	± 0.4 a	8.3	± 0.5 **a**	3.862	0.024
TDS	460.1	± 72.3 **b**	485.8	± 60.8 **a**	478.1	± 64.6 **a**	6.749	0.002

On the other hand, the differences among months in all the measured factors were highly significant. The monthly fluctuations of environmental factors at the three investigated sites during the period of investigation are shown in figure (3).

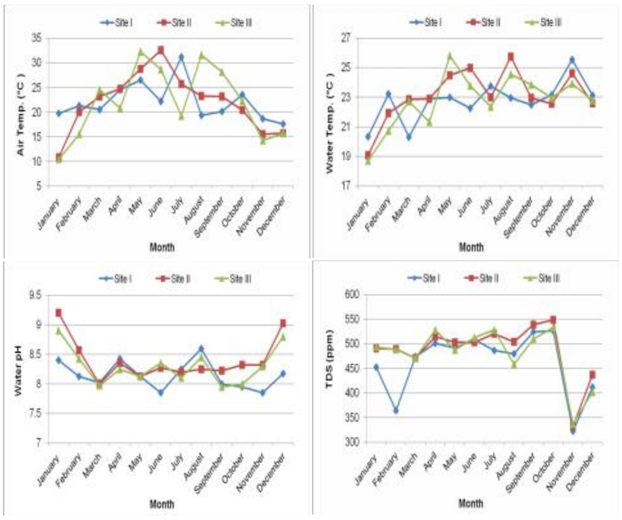

Figure 3 Monthly variations of environmental factors at the three studied sites at Wadi Al-Arj stream during the period of study.

Macroinvertebrates composition and abundance

The mean density and relative abundance of the invertebrate taxa collected from the three studied sites during the period of investigation are illustrated in Table (2). The mean density of the total invertebrates in site I was 107.08 Indv/h, constituting 38.94% of the total catch from the three studied sites. The mean density of invertebrate collected from site II, was 77.92 Indv/h, constituting 28.34% from the total catch while this value in site III was 89.97 Indv/h, constituting 32.72.34%. The composition of invertebrate community in studied sites was 17 taxa in site II and site III while in site I was 20 taxa. All

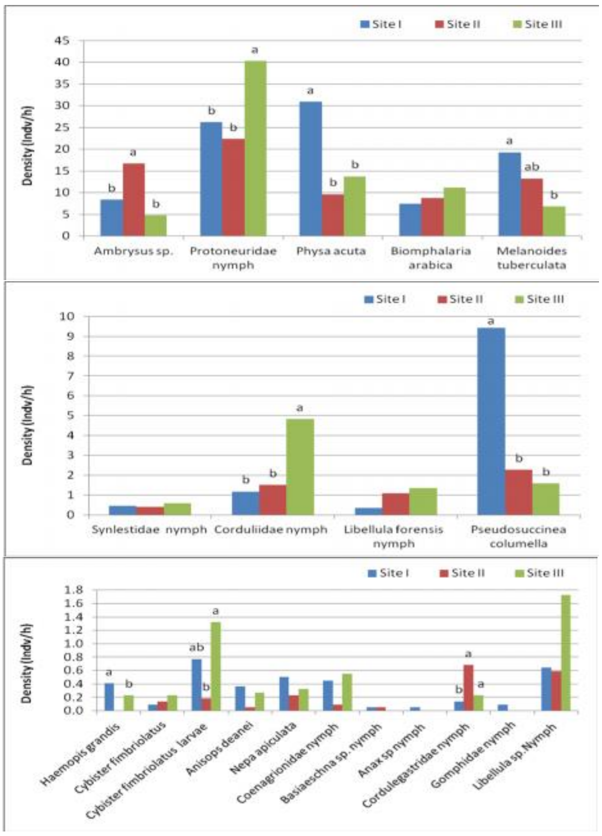

Figure 4 The mean density of Invertebrate taxa at different investigated sites during the period of study (The similar characters for each taxon show no significant difference).

sp. nymph, *Pseudosuccinea columella*, *Biomphalaria arabica* and *Melanoides tuberculata*, whereas there was no significant difference in the density of the rest of the collected taxa. Generally, the collected taxa show the high abundance in March except in case of Protoneuridae nymph and *Melanoides*

Table 2 Mean values of density (Indv/h) and relative abundance (%) for the monthly collected Invertebrate taxa at investigated sites

	Site I		Site II		Site III	
	Indv/h	**%**	**Indv/h**	**%**	**Indv/h**	**%**
Haemopis grandis	0.41	0.38	-----	-----	0.23	0.26
Cybister fimbriolatus	0.09	0.08	0.14	0.18	0.23	0.26
Cybister fimbriolatus larvae	0.77	0.72	0.18	0.23	1.32	1.47
Ambrysus sp.	8.36	7.81	16.68	21.41	4.77	5.30
Anisops deanei	0.36	0.34	0.05	0.06	0.27	0.30
Nepa apiculata	0.50	0.47	0.23	0.30	0.32	0.36
Coenagrionidae nymph	0.45	0.42	0.09	0.12	0.55	0.61
Protoneuridae nymph	26.23	24.51	22.32	**28.64**	40.27	**44.76**
Synlestidae nymph	0.45	0.42	0.41	0.53	0.59	0.66
Basiaeschna sp. nymph	0.05	0.05	0.05	0.06	-----	-----
Anax sp nymph	0.05	0.05	-----	-----	-----	-----
Cordulegastridae nymph	0.14	0.13	0.68	0.87	0.23	0.26
Corduliidae nymph	1.18	1.10	1.50	1.93	4.82	5.36
Gomphidae nymph	0.09	0.08	-----	-----	-----	-----
Libellula sp.Nymph	0.64	0.60	0.59	0.76	1.73	1.92
Libellula forensis nymph	0.36	0.34	1.09	1.40	1.36	1.51
Pseudosuccinea columella	9.41	8.79	2.27	2.91	1.59	1.77
Physa acuta	30.86	**28.84**	9.64	12.37	13.73	15.26
Biomphalaria arabica	7.41	6.93	8.77	11.26	11.14	12.38
Melanoides tuberculata	19.27	18.01	13.23	16.98	6.82	7.58
Total	**107.08**	**38.94**	**77.92**	**28.34**	**89.97**	**32.72**

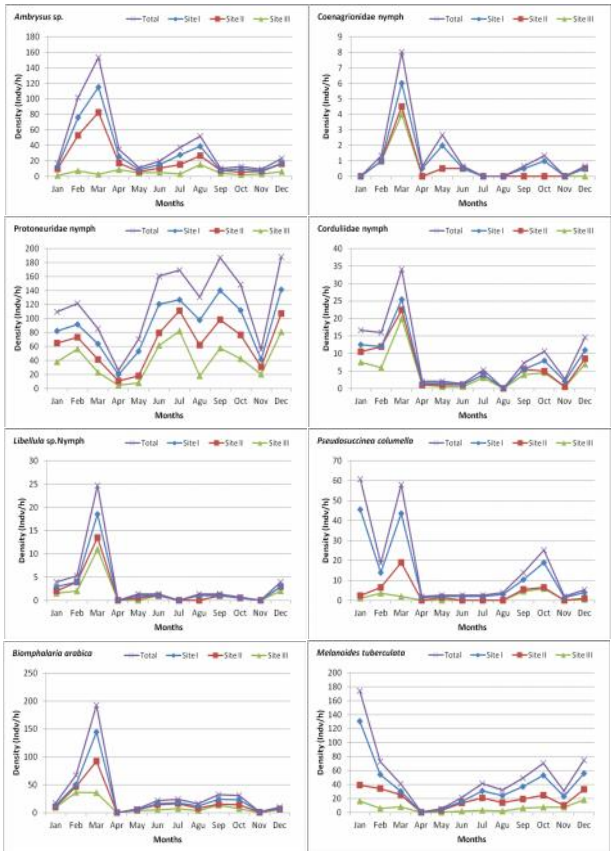

Figure 5 Monthly variations for the mean density (Indv/h) of collected macroinvertebrates at the studied sites during the period of investigation.

tuberculata its high abundances were recorded in December and January respectively (Fig. 5).

Ambrysus sp. present through all the year in present study area. The abundance of this specie shows two peaks during the year in March and August (Fig. 5). Coenagrionidae nymph represent in low density. As general it recorded in March, and May in all study sites (Fig. 5). Protoneuridae nymph recorded in all studied sites in high density. It is recorded in all studied months. The abundance of this specie shows four peaks during the year in February, July, September and December (Fig. 5). The high abundance of Corduliidae nymph was in March, July and the low abundance was recorded in April, May, June, August and November (Fig. 5). *Libellula* sp. nymph usually presents during winter season and reach the peak at the begging of spring in March (Fig. 5). The abundance of *Pseudosuccinea columella* shows three peaks during the year in January at site I, in Mrch at site I and site II and in October at all sites (Fig. 5). *Biomphalaria Arabica* not recorded form all studied sites in April and showed the highest density in March (Fig. 5). Low density of *Melanoides tuberculata* was recorded in site II not recorded from site I and III in April. The density of this species start to increase in all studied sites from May to reach the high density in Decmber at site II and site III and in January at site I (Fig. 5).

Total invertebrate abundance, richness and Shannon diversity

Table (3) summarized the collected invertebrate total abundance, taxa richness and Shannon diversity at the studied sites. Statistical analyses showed no significant differences among sites in these variables. It was noticed that these variables showed different patterns of monthly variations. The lower value of total abundance of invertebrate were recorded in April at all studied sites, 14 Indv/h, 18 Indv/h and 27 Indv/h at site III, site II and site I respectively. While the highest values were recorded in January at site I (268 Indv/h) in March at site II (243 Indv/h) and in September at site III (140 Indv/h).

Taxa richness reached the highest peak value in February at site III (15 taxa) and the lowest values (3 taxa) in April in the same site. The high taxa richness in site I(14 taxa) and site II (13 taxa) were recorded in March. While the lower values of taxa richness were recorded in July at site I (7 taxa) and in November at site II (5 taxa). Shannon-Wiener's diversity index reached the peak values during March at site I (1.96) and site III (2) while at site II (1.82) it reached the high value in May. On the other hand, the lowest peak values of Shannon index were recorded in April at site III (0.86), in May at site I (1.02) and in November at site II (1.11).

Table 3 Summary of Invertebrate total abundance, Taxa richness and Shannon diversity at the three investigated sites during period of investigation.

Months	Total Abundance			Richness			Shannon Diversity (H)		
	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III
January	268	77	94	10	11	12	1.37	1.76	1.80
February	95	127	131	10	11	15	1.75	1.8	1.74
March	217	243	124	14	13	13	1.96	1.76	2.00
April	27	18	14	8	6	3	1.53	1.17	0.86
May	47	23	23	10	10	9	1.02	1.82	1.77
June	70	57	106	10	9	13	1.36	1.71	1.29
July	63	90	121	7	9	8	1.61	1.71	1.09
August	76	84	59	10	10	8	1.64	1.54	1.65
September	113	69	140	10	10	11	1.62	1.34	1.55
October	154	75	98	11	8	11	1.68	1.45	1.71
November	41	18	40	9	5	9	1.54	1.11	1.47
December	79	67	130	9	13	13	1.49	1.75	1.40

DISCUSSION

The present results showed there are twenty macroinvertebrates' taxa were recorded in Wadi Al-Arj. This is a relatively low number of taxa when compared to other tropical streams (Burt, 2003; Victor and Al-Mahrouqi 1996; Victor and Ogbeibu, 1985, 1991; Ogbeibu and Victor, 1989). Abd El-Wakeil and Al-Thomali (2013) related this low number of invertebrates in Wadi Al-Arj to anthropogenic impact in survival of invertebrates in the stream and the roughness of the environmental conditions associated with the hot and arid climate.

Odonata nymphs are widespread and often the major components of all present studied sites. The heterogenous abundance and distribution of taxa amongst the different biotopes at the same location is usual in temperate and tropical streams (Victorr and Al-Mahrouqi 1996). This is a sign of niche availability governed by abiotic and biotic factors. All Odonata recorded in this stream either have terrestrial life stages or have adaptations for surmounting inauspicious conditions such as drought.

In the present study, there are two invertebrates registered only in site I; *Anax* sp. nymph and Gomphidae nymph. This site may have suitable environmental conditions than the other two sites. It shows the relatively low water pH and total dissolved salts. El-Shimy and Obuid-Allah (1992), whose worked on freshwater invertebrates in Nile at Assiut, Egypt, where they noticed the richness of fauna affected by environmental factors. The diversity of microhabitats and the retention of food resources play an important role in invertebrates community composition and structure (Gray, 1974; Gambi and Giangrande, 1986). Other reasons which may play a role in invertebrates richness in these sites is the vegetation. Macroinvertebrate assemblages appear to be strongly influenced by vegetation (Battle *et al*., 2001).

Another reason may be considered as factor effect the differences in abundance and distribution of macroinvertebrates is vegetations. Barton *et al.*, (1985), illustrated that the vegetation within the stream channels and riparian vegetation significantly affects the structure and function of macroinvertebrates. The streamside forests affect directly on the food quality and quantity for macroinvertebrates via inputs of particulate food such as leaf litter, soils, wood, etc. and indirectly affect the structure and productivity of microbial (algae, bacteria) food web through shading and modifying the levels of organic matter and nutrients (Behmer and Hawkins 1986; Cummins *et al*., 1989; Bilby and Ward, 1991). The molluscan gastropods are represented in relatively high density in all studied sites. Lacoursière *et al*. (1975) and Vincent *et al*. (1982); they suggested that gastropod variability may be explained by abiotic factors (depth, current and sediment). Also Strzelec and Królczyk (2004) indicated that many gastropod species are tolerant to most physicochemical water parameters and their occurrence is affected by the quality of bottom sediments and vegetation abundance and reported that the most suitable substrate for snails in rivers is a sandy bottom covered with thin layer of organic silt. Similar observations were also reported by (Strzelec 1993 and Michalik-Kucharz *et al.*, 2000).

Many studies showed the positive influence of macrophytes abundance on the number of freshwater snails (Lodge and Kelly, 1985; Brönmark, 1985 and Costil and Clement, 1996). High density of molluscs in the present studied sites needs more extensively study to show the impact of these molluscs in the environmental health status, scince freshwater molluscs have been known to play significant roles in the public and veterinary health (Supian and Ikhwanuddin, 2002; Hussein *et al.*, 2011).

The abundance of collected invertebrates has monthly variations in all studied sites. Generally, invertebrates show the high abundance in March except in case of Protoneuridae nymph and *Melanoides tuberculata* its high abundances were recorded in December and January respectively. The increased numbers of invertebrates during March; begin of spring may be due to favorable conditions of environmental factors during this period of the year which includes physical, chemical and biological factors. Many environmental factors change seasonally and play a major role in structuring the benthic community (Ward, 1998; Ngqulana, 2012; Simboura *et al*., 2012).

The seasonal variation of macroinvertebrates may be related to alternately between floods and drought. The streams which are more likely to spates have less abundant and less varied fauna than others (Hynes, 1970; Allan, 1995; Hussain, 2011). This has been recognized by many studies in different countries and it is doubtless a widespread phenomenon (Hynes, 1970; Grubaugh *et al*. 1996; Negishi *et al*. 2002; Younes-Baraille *et al*., 2005; Donohue *et al*., 2006; Hussain, 2011). An additional effect of flooding is that in areas where spates are seasonally regular there tends to be a corres-ponding seasonal alteration in the density of fauna. Hussain (2011) found that in the mountain streams with spring runoff of melt water, there are always fewest animals in the time from April to June. The macroinvertebrates of communities changeable flows show a high resistance to moderate flooding (Resh *et al*., 1988; Puig *et al*., 1991), and need little time to convalesce. Populations of macroinvertebrates are severely depressed after extreme flooding, but typically recover very rapidly (Elwood and Waters 1969; Hilsenhoff, 1996).

References

Abd El-Aziz, F. A., 2012. Taxonomical and Ecological Studies on Freshwater Benthic Invertebrates at Assiut Governorate, Egypt. Ph.D Thesis, Faculty of Science, Assiut University, Egypt.

Abd El-Wakeil, K. F. and M. M. Al-Thomali 2013. Community structure of aquatic macro invertebrates inhabiting Wadi Al-Arj, Taif, Kingdom of Saudi Arabia. Life Science Journal 10(4): 1199-1207. http://www.lifesciencesite.com

Abd El-Wakeil, K.F., A. H. Obuid-Allah, A. H. Mohamed and F. A. Abd El-Aziz, 2013. Community structure of molluscans in River Nile and its branches in Assiut governorate, Egypt. Egyptian Journal of Aquatic Research 39: 193–198.

Abel, P. D. 1989. Water Pollution Biology. Ellis Horwood, Chichester, UK, pp. 232.

Abueshey, M. M. 2012. Effect of Inland discharge of Sewage Effluent on pollution of Soil, Well water and Plants along Wadi Al-Arj in Taif area. Ph.D. Thesis, King Abdulaziz University, Saudi Arabia.

Allan, J. D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall, New York, pp. 388.

Al-Shaibani, A. M. 2008. Hydrogeology and hydrochemistry of a shallow alluvial aquifer, western Saudi Arabia. Hydrogeology Journal 16: 155–165.

Arunachalam, M., K. C. Madlhusoodanannair, J. Vijverberg, K. Kortmulder and H. Suriyanarayanan, 1991. Substratum selection and seasonal variation in densities of invertebrates in stream pools of a tropical river. Hydrobiologia 213: 141–148.

Balian, E. V., H. Segers, C. Lévèque and K. Martens, 2008. The Freshwater Animal Diversity Assessment: an overview of the results. Hydrobiologia 595: 627–637.

Barton, D. R., W. D. Taylor and R. M. Biette, 1985. Dimensions of riparian buffer strips required to maintain trout habitat in Southern Ontario streams. North American Journal of Fisheries Management 5: 364-378.

Battle, J. M., S. W. Golladay and B. Clayton, 2001. Aquatic macroinvertebrates and water quality characteristics in five wetland types: preliminary results on biomonitoring, pp. 333–336.

Behmer, D. J. and C. P. Hawkins, 1986. Effects of overhead canopy on macro invertebrate production in a Utah stream. Freshwater Biology 16: 287-300.

Bilby, R. E., J. W. Ward, 1991. Characteristics and function of large woody debris in streams draining old growth, clear cut, and second-growth forests in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 48: 2499-2508.

Boulton, A.J., H. M. Valett, and S. G. Fisher, 1992. Spatialdistribution and taxonomic composition of the hyporheos of several Sonoran Desert streams. Archiv fur Hydrobiologia 125 (1): 37-61.

Brönmark, C. 1985. Interactions between macro- phytes, epiphytes and herbivores an experimental approach. Oikos 45: 26-30.

Burt, J. 2003. Aquatic macroinvertebrates of an intermittent stream in the arid Hajar Mountains, Oman. Tribulus 13(2): 14-22.

Cortes, R. M. V., M. T. Ferreira, S. V. Oliveira and D. Oliveira, 2002. Macroinvertebrate community structure in a regulated river segment with different flow conditions. River Research and Applications 18:367–382.

Costil, K. and B.Clement, 1996. Relationship between freshwater gastropods and plant communities reflecting various trophic levels. Hydrobiologia 321: 7-16.

Cummins K. W., M. A. Wilzbach, D. M. Gates, J. B. Perry and W.B. Taliaferro, 1989. Shredders and riparian vegetation. Bioscience 39: 24-30.

Donohue, I., M. L. McGarrigle and P. Mills, 2006. Linking catchment characteristics and water chemistry with the ecological status of Irish rivers. Water Research 40: 91-98.

Downes, B. J., P. S. Lake and E. S. G. Schreiber, 1995 Habitat structure and invertebrate assemblages on stream stones: A multivariate view from the riffle. Australian Journal of Ecology 20: 502–514.

El-Shimy, N. A. and A. H. Obuid-Allah, 1992. A survey of some freshwater invertebrates in the Nile at Assiut. Journal of the Egyptian German Society of Zoology 7: 363-376.

Elwood, J. W. and T. F. Waters, 1969. Effects of floods on food consumption and production rates of a stream brook trout population. Transactions of the American Fisheries Society 98(2):253-262.

Gambi, M. C. and A. Giangrande, 1986. Distribution of soft-bottom polychaetes in two coastal areas of the Tyrrhenean sea (Italy): Structural analysis. Estuarine coastal shelf Science 23: 847-862.

Gayraud, S. and M. Philippe, 2001. Does subsurface interstitial space influence general features and morphological traits of the benthic macroinvertebrate community in streams? Archiv für Hydrobiologie 151: 667–686.

Gray, J. S. 1974. Animal-sediment relationships. Oceanography and Marine Biology: Annual Review 12: 223-261.

Grubaugh, J. W., J. B. Wallace and E. S. Houston, 1996. Longitudinal changes of macroinvertebrate communities along an Appalachian stream continuum. Canadian Journal of Fisheries and Aquatic Sciences 53:896-909.

Hellawell, J. M. 1986. Biological Indicators of Freshwater Pollution and Environmental Management. Elsevier, London, pp. 518.

Hilsenhoff, W. L. 1996. Effects of a catastrophic flood on the insect fauna of Otter Creek, Sauk County, Wisconsin. Transactions of the Wisconsin Academy of Sciences 84:103-110.

Hussain, Q. A. 2011. An Ecological Study of Doodhganga and its Drainage Basin- A Lotic System of Kashmir. PhD. Thesis, P. G. Department of Environmental Science, University of Kashmir, Srinagar.

Hussein, M.A., A. H. Obuid-Allah, A. A. Mahmoud and H. M. Fangary, 2011. Population dynamics of freshwater snails

(Mollusca: Gastropoda) at Qena Governorate, Upper Egypt. Egyptian Academic Journal of Biological Sciences 3(1): 11 -22

Hynes, H. B. N. 1970. The Ecology of Running Waters. Liverpool University Press, England. p. 555.

Ibrahim, A. M., H. M. Bishai and M. T. Khalil, 1999. Freshwater Molluscs of Egypt. Department of Nature Protection, Egyptian Environmental Affairs Agency, Cairo, Egypt.

Kalkman, V. J., V. Clausnitzer, K. D. B. Dijkstra, A. G. Orr, D. R. Paulson and J. van Tol, 2008. Global diversity of dragonflies (Odonata) in freshwater. Hydrobiologia 595: 351–363.

Klemm, D. J. 1972. Freshwater Leeches (Annelida: Hirudinea) of North America Issue 8 of Biota of freshwater ecosystems identification manual Water pollution control research series U.S. Environmental Protection Agency

Lacoursière, E., G. Vaillancourt and R. Couture, 1975. Relation entre les plantes aquatiques et les Gastéropodes (Mollusca: Gastropoda) dans la région de la centrale nucléaire de Gentilly I (Quèbec). Canadian Journal of Zoology 53: 1868-1874.

Lodge, D. M. and P. Kelly, 1985 Habit disturbance and the stability of freshwater gastropods populations. Oecologia 68: 111-117.

Magniez, G. J. and J. H. Stock, 1999. Consequences of the discovery of Stenasellus (Crustacea, Isopoda, Asellota) in underground waters of Oman (Arabian Peninsula); Stygofauna of Oman, 4. Contributions to Zoology 68: 173-179.

Malmqvist, B. and C. Otto, 1987. The influence of substratum stability on the composition of stream benthos; an experimental study. Oikos 48: 33–38.

Marchant, R., L. Metzeling, A. Graesser and P. Suter, 1985. The organization of macroinvertebrate communities in the major tributaries of the Latrobe River, Victoria, Australia. Freshwater Biology 15: 315–331.

Martinez-Ansemil, E., N. Giani, and B. Sambugar, 2002. Oligochaetes from underground waters of Oman with descriptions of two new species of Phreodrilidae (Oligochaeta): Antarctodrilus arabicus n. sp. and Phreodrilus stocki n. sp.; Stygofauna of Oman, 7. Contributions to Zoology. Vol. 71:147-1 58.

Michalik-Kucharz, A., M. Strzelec and W. Serafiński, 2000. Malacofauna of rivers in Upper Silesia (Southern Poland). Malakologische Abhandlungen 20(12): 101-109.

Negishi, J. N., M. Inoue and M. Munokawa, 2002. Effect of channelization on stream habitat in relation to a spate and flow Refugio for macro-invertebrates in Northern Japan. Freshwater Biology 47: 1515-1529.

Nesemann, H., R.D.T. Shah and D. N. Shah, 2011. Key to the larval stages of common Odonata of Hindu Kush Himalaya, with short notes on habitats and ecology. Journal of Threatened Taxa 3(9): 2045–2060.

Neubert, E. 1998. Annotated checklist of the terrestrial and freshwater mollusks of the Arabian Peninsula with descriptions of new species. Fauna of Arabia 17: 333-461.

Ngqulana, S. G. 2012. Spatial and temporal distribution of the benthos in the Mfolozi Msunduzi Estuary, Kwa Zul Natal. M.Sc. Thesis, Zululand University.

Ogbeibu, A. E. and R. Victor, 1989. The effects of road and bridge construction on the bank-root macrobenthic invertebrates of a southern Nigerian stream. Environmental Pollution 56: 85–100.

Puig, M. A., M. Aboal and A. De Sostoa, 1991. New approaches to Mediterranean fluvial communities. Oecologia aquatica 10: 13-20.

Raza, M. J. 2004. Groundwater Quality Evaluation and Vulnerability Assessment of Wadi Al-Arj Alluvium Aquifer, Taif, Saudi Arabia. M.Sc. Thesis, King Fahd University of Petroleum and Minerals.

Resh, V. H., A.V Brown, A.P. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S.R. Reice, A. L. Sheldon, J. B. Wallace, and R. C. Wissmar, 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-455.

Roberts, D. M. and R. J. Irving-Bell, 1997. Salinity and microhabitat preferences in mosquito larvae from southern Oman. Journal of Arid Environments 37: 497-504.

Rosenberg, D. M. and V. H. Resh, 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York, NY.

Sawyer, R.T. 1972. North American Freshwater Leeches. Exclusive of the Piscicolidae with a Key to All Species. University of Illinois Press Urbana, Chicago, and London.

Schneider, W. and H. J. Dumont, 1997. The dragonflies and damselflies (lnsecta: Odonata) of Oman. An updated and annotated checklist. Fauna of Saudi Arabia 16: 89-1 10.

Segars, H. and H. J. Dumont, 1993. Rotifera from Arabia, with descriptions of two new species. Fauna of Saudi Arabia 13: 3-26.

Simboura, N, A. Zenetos, M. A. Pancucci-Papadopoulou, S. R. Eizopoulou and N. Streftaris, 2012. Indicators for the Sea-foor Integrity of the Hellenic Seas under the European Marine Strategy Framework Directive: establishing the thresholds and standards for Good Environmental Status. Mediterranean Marine Science 140-152.

Strzelec, M. 1993. Ślimaki (Gastropoda) antropogenicznych środowisk wodnych Wyżyny Śląskiej [Snails (Gastropoda) of anthropogenic water environments in Silesian Upland]. Prace Naukowe Uniwersytetu Śląskiego, Katowice, 1358, 104 pp.

Strzelec, M. and A. Królczyk, 2004. Factors affecting snail (Gastropoda) community structure in the upper course of the Warta river (Poland). Biologia, Bratislava 59(2): 159-163.

Supian, Z. and A. M. Ikhwanuddin, 2002. Population dynamics of freshwater molluscs (Gastropod: Melanoides tuberculata) in Crocker Range Park, Sabah. ASEAN Review of Biodiversity and Environmental Conservation (ARBEC), July-September 1, 1-19.

Townsend, C. R. 1989. The patch dynamics concept of stream community ecology. Journal of the North American Benthological Society 8: 36–50.

Victor, R. and A .E. Ogbeibu, 1991. Macroinvertebrate communities in the erosional biotope of an urban stream in Nigeria. Tropical Zoology 4: 1–12.

Victor, R. and A. E. Ogbeibu, 1985. Macrobenthic invertebrates of a stream flowing through farmlands in southern Nigeria. Environmental Pollution (Series A) 39: 337–349.

Victor, R. and A. I. S. Al-Mahrouqi, 1996. Physical, chemical and faunal characteristics of a perennial stream in arid northern Oman. Journal of Arid Environments 34: 465-476.

Victor, R. and J. R. Victor, 1997. Some aspects of the ecology of littoral invertebrates in a coastal lagoon in Southern Oman. Journal of Arid Environments 37: 33-44.

Vincent, B., N. Lafontaine and P. Caron, 1982 Facteurs influencant la structure des groupements de macroinvertébrés benthiques et phytophiles dans la zone littorale du Saint-Laurent (Québec). Hydrobiologia 97: 63-73.

Walker, B. 1959. The Mollusca. In Ward, H.B. and G.C. Wipple (eds), FreshWater Biology, 2nded.(ed.W.T.Ed-mondson). John Wiley and Sons. Inc., New York, pp. 957– 1020.

Walker, D. H. and A .R. Pittaway 1987. lnsects of Eastern Arabia. MacMillan, London, UK.

Ward, J. V. 1998. Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation. Biological Conservation 83: 269–278.

Williams, D. D. and K. A. Moore, 1986. Microhabitat selection by a stream-dwelling amphipod: a multivariate analysis approach. Freshwater Biology 16: 115–122.

Younes-Baraille, Y., X. F. Garcia and J. Gagneur, 2005. Impact of longitudinal and seasonal changes of water quality on the benthic macro-invertebrate assemblages of the Andorran streams. Comptes Rendus Biologies 328: 963-976.

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