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RESEARCH ARTICLE

Diversity of zooplankton inhabiting inland waters of North West region (Tabuk) of Saudi Arabia.

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Abstract

The main objective of this paper to investigate the diversity of common zooplankton inhabiting inland waters of North West region (Tabuk) of Saudi Arabia. The study covered 76 sites. The results revealed the presence of 38 taxa belonging to phylum Arthropoda and Rotifera. Based on the frequency of occurrence, taxa recorded could be ordered into: constant, accessory and accidental taxa. The constant taxa recorded were represented by one taxon namely: Family Chironomidae. The accessory taxa were represented by 4 taxa: Ostracoda, Diptera pupae, Cyclopoida (Copepoda), and Culicidae larvae. The accidental taxa were represented by the rest of taxa (33 taxa).

Introduction

Zooplanktons are minute heterotrophic organisms present in water bodies at various depths in every type of aquatic environment (Majagi and Vijaykumar, 2009). Zooplankton forms an important link in the dynamic ecosystems of estuaries, bays, rivers and lakes and performs several vital functions within lake ecosystems including transfer of energy and nutrients from producers to secondary consumers, the sequestration of nutrients, and the removal of phytoplankton from the water column (An et al., 2012). Zooplankton species are usually considered as good indicators of environmental changes (Rajashekhar et al., 2010). Correct identification of freshwater organisms is essential to understanding their ecology. The aquatic organisms interact with environment to alter water quality and perform ecology "services" such as decomposition and nutrient cycling (Singh et al., 2012). The study of freshwater fauna especially zooplankton is extensive and complicated due to environmental, physical, chemical and geographic variations involving ecological, extrinsic and intrinsic factors (Majagi and Vijaykumar, 2009). The study of distribution of zooplankton is useful for general monitoring of certain environmental aspects, such as hydrographic events, particularly eutrophication, pollution warning trends and long term changes which are signs of environmental disturbances (Michael, 1984). Zooplankton research became increasingly important in recent years since these floating organisms serve as a reproductive base for both marine and freshwater ecosystems (Mahdy, 2005). Cladocera and Copepoda regenerate nitrogen and phosphorus in the soluble available forms. This enhances phytoplankton productivity, speeds nutrient cycling and tightens coupling between these trophic levels (Carney, 1990). Some modifications in zooplankton diversity are response to the environmental stress caused by eutrophication (Perbiche-Neves et al., 2013).

Knowledge about freshwater fauna in the Arabian Peninsula is extremely limited (Victor and Al-Mahrouqi, 1996 and Burt, 2003). Balian et al. (2008) indicated the lack of data from the Afro tropical (e.g. Southeast Asia) about biodiversity in freshwater ecosystems. On reviewing literature focusing on the inland water fauna of Saudi Arabia, revealed that it covered only small regions of the Peninsula. For example Al-Asgah et al. (1989) studied the perennial freshwater reservoirs and valleys in Saudi Arabia to determine the zooplankton species. The survey of Krupp et al. (1990) was conducted in the central and western parts of Saudi Arabia. The work of Siddiqui and Al-Harbi (1995) was focused on the ecology of Wadi Hanifah stream with reference to animal communities. Al-Ghanim (2012) studied the distribution and composition of zooplankton in Wadi Hanifah stream Riyadh. Abd El-Wakeil and Al-Thomali (2013) studied the community structure of aquatic macro invertebrates inhabiting Wadi

Al-Arj, Taif. Montaser et al. (2014) studied the community structure of zoobenthos in some freshwater bodies in Taif, Saudi Arabia. Aloufi and Obuid-Allah (2014) studied zooplankton communities inhabiting inland waters of Al-madinah almonawwarah region; Saudi Arabia. To the best of the present authors´ knowledge and as far as can be ascertained, the North West region of Saudi Arabia (Tabuk) has not yet gained a satisfactory attention. The present study is a correspondent step toward the survey of inland water fauna of the North West region of Saudi Arabia (Tabuk). The main objective of this investigation to study the diversity of zooplankton inhabiting inland water of North West region (Tabuk) of Saudi Arabia. It was focused on zooplankton communities, except Protozoa, inhabiting inland water of Tabuk region.

Materials and Methods:

Samples were collected randomly during day time of the winter months (December 2013 till February 2014) using zooplankton net with mesh size about100 µm. Samples were preserved in absolute ethanol in the field. Examination of samples was carried out under binocular microscope equipped with a camera. Some physico-chemical parameters of the investigated sites were taken using two probe electrodes. One probe measures pH/conductivity/total dissolved salts (TDS)/Salinity and temperature (Model: Multi-Parameter PCSTester tm 35-series. UOM: EA BOO4G8PWBO) and the other electrode measures dissolved oxygen (Model: DO600-ExStik II). Different keys and references were used for identification: Lehmkuhl (1979), Rogers (2002), Carling et al. (2004), Witty (2004) and Timms (2012). The map was prepared using remote sensing methods where the achieved images data of the map was downloaded by Landsat 8 (2014) given by United States Geological Survey (USGS) (http://earth explorer. usgs.gov/). Also, The Environment visualizing images (ENVI) software virgin 5 was used for layer mosaics, stacking and image sub-sitting. Imported co-ordinates and map lay-out were prepared using ARCMAp10.1 software.

Results:

Sites of collection (Figure 1).

The sites investigated included 76 sites covered Tabuk region. They could be classified into: **Permanent lakes** (19 sites), **temporary ponds** (29 sites), **streams** (11 Sites), **wades** (5 Sites), **springs** (3 Sites) and **wells** and **reservoirs** (9 Sites). Some physicochemical parameters were measured. The maximum depth at the investigated sites ranged between 10cm-800cm. The temperature of air ranged between 10°C-37°C. Temperature of water ranged between 8°C-39°C. Conductivity ranged between 192µS- >20.00 mS. Total dissolved salts ranged between 0.121ppt->10.00ppt. The dissolved oxygen ranged between 1.4 mg/L-19.03 mg/L. The pH ranged between 7-11. Some of the investigated sites were inhabited by wild plants (sites 1:13 and 46). The dominant plants recorded included *Phragmites australis*, *Tamarix nilotica* and Palm trees. Some birds, including migratory and resident ones, were observed during sampling at certain sites which included *Vanellus spinosus*, *Passer domesticus*, *Streptobelia senegalensis* and *Motacilla alba.*

Taxa recorded (Table1):

Thirty eight taxa belonging to phylum Rotifera and Arthropoda were recorded. The arthropod taxa included insects, crustaceans and water mites. Class Insecta was represented by 18 taxa constituted 47% of total taxa collected and belonging to six orders: Hemiptera (4 families), Coleoptera (2 families), Diptera (5 families), Odonata (2 families), Ephemeroptera (1 family), and Collembola (2 sub-orders: Arthropleona and Symphypleona). Crustacea was represented by 18 taxa constituted 47% of the total taxa collected and belonging to: Order Anostraca (3 species), Order Notostraca (one species), Order Conchostraca (one species), Order Cladocera (4 families), Sub-Class Copepoda (2 orders) and Class Ostracoda. Water mites and rotifers each constituted 3% of the total taxa collected.

The above mentioned taxa were divided into constancy classes according to the system adopted by Weis-Fogh (1948) and used by several authors like Hussein (1972), Obuid-Allah (2000) and Abdel-Wakeil (2013) as follows:- Constant taxa: present in more than 50% of the samples. - Accessory taxa: present in 25-50% of the samples. - Accidental taxa: present in less than 25% of the samples.

According to the system mentioned above, the constant taxa recorded were represented by one taxon namely: Family Chironomidae (Diptera) (51%). The accessory taxa were represented by 4 taxa: Ostracoda (47%), Diptera pupae (41%), Cyclopoida (Copepoda) (34%), and Culicidae larvae (30%). The accidental taxa were represented by the rest of taxa (33 taxa). The top six accidental taxa recorded were: Family: Ceratopogonidae (Order Diptera) (22%), *Daphnia longispina* (Cladocera) (21%), Family: Libellulidae (Odonata) (17%), Family: Siphlonuridae (Ephemeroptera) (17%), Family: Pleidae (Hemiptera) (16%) and Family: Ephydridae (Diptera) (14%). The least accidental taxa recorded were represented by Family: Notonectidae and Belostomatidae (Hemiptera), Family:

Tipulidae (Diptera), the anostracan species: *Artemiopsis stephanssoni* and *Eubranchipus* sp., the conchostracan species: *Coenestheriella* sp. and the cladoceran species: *Pleuroxus trigonellus*.

Following the above mentioned classification of the investigated sites into six groups: permanent lakes, temporary ponds, streams, wades, springs and wells and reservoirs. One can conclude that the temporary ponds and permanent lakes were the richest groups of sites in taxa number where they harbored 30 and 28 taxa; respectively. The (wells and reservoirs) and wades came in the second order where they harbored 17 and 13 taxa; respectively. The least types of sites in taxa number were springs and streams having 10 and 8 taxa; respectively. Referring to taxa recorded in the above mentioned sites; Ostracoda and Chironomidae had the maximum percentage of frequency of occurrence in temporary ponds (16% for each). Ostracoda, Cyclopoida and *Daphnia longispina* had the maximum percentage of frequency of occurrence in permanent lakes with 20%, 17%, and 17%; respectively. In wells and reservoirs, Diptera pupae, Chironomidae, and Culicidae (Larvae) recorded the maximum values (8%, 7%, and 7%; respectively). In wades, Ceratopogonidae and Diptera pupae recorded the highest values (5% for each). In springs, Chironomidae and Coenagrionidae recorded the highest values (4% and 3%; respectively). In streams, Chironomidae and Diptera pupae recorded the highest values (9% and 5%; respectively).

Table (1): Illustrates different taxa collected from the investigated sites and their occurrence during the period of investigation

Taxa No.	Taxa Collected	F	%F
	Class: Insecta:		
	a-Order: Hemiptera		
1	Family: Pleidae	12	16
2	Family: Notonectidae	1	1
3	Family: Corixidae	9	12
4	Family: Belostomatidae	1	1
	b-Order: Coleoptera		
5	Family: Dytiscidae	10	13
6	Family: Hydrophilidae	3	4
	c-Order: Diptera		
7	Diptera pupa	31	41
8	Family: Chironomidae	39	51
9	Family: Ephydridae	11	14
10	Family: Culicidae (Larva)	23	30
11	(Pupa)	4	5
12	Family: Tipulidae	1	1
13	Family: Ceratopogonidae	17	22
	d-Order: Odonata -Anisoptera		
14	Family: Libellulidae	13	17
	- Zygoptera		
15	Family: Coenagrionidae	7	9
	e-Order: Ephemeroptera		
16	Family: Siphlonuridae	13	17
	f- Order: Collembola		
17	**S.O: Arthropleona**	4	5
18	**S.O: Symphypleona:**	3	4
	Sub-Phylum: Crustacea		
	Class: Branchiopoda		
	1-Order: Anostraca		
19	-*Streptocephalus seali*	6	8
20	-*Artemiopsis stephanssoni*	1	1
21	-*Eubranchipus* sp.	1	1
	2-Order: Notostraca		

22	Family: Triopsidae *-Triops longicaudatus*	2	3
23	**3-Order: Conchostraca** - *Coenestheriella* sp.	1	1
	4-Order: Cladocera		
	Family: Daphnidae		
24	*Daphnia longispina*	16	21
25	*Daphnia retrocurva*	2	3
26	*Daphnia magna*	9	12
27	*Ceriodaphnia reticulata*	4	5
28	*Scapholeberis aurita*	8	11
29	*Simocephalus exspinosus*	8	11
	Family: Chydoridae		
30	*Alona bukobensis*	3	4
31	*Pleuroxus trigonellus*	1	1
	Family: Macrothricidae		
32	*Macrothrix* sp.	3	4
	Family: Moinidae		
33	*Moina micrura*	10	13
	-Sub-Class: Copepoda		
34	**Order: Calanoida**	5	7
35	**Order: Cyclopoida**	26	34
36	**-Class: Ostracoda**	36	47
37	Mites	7	9
38	**Phylum: Rotifera**	6	8

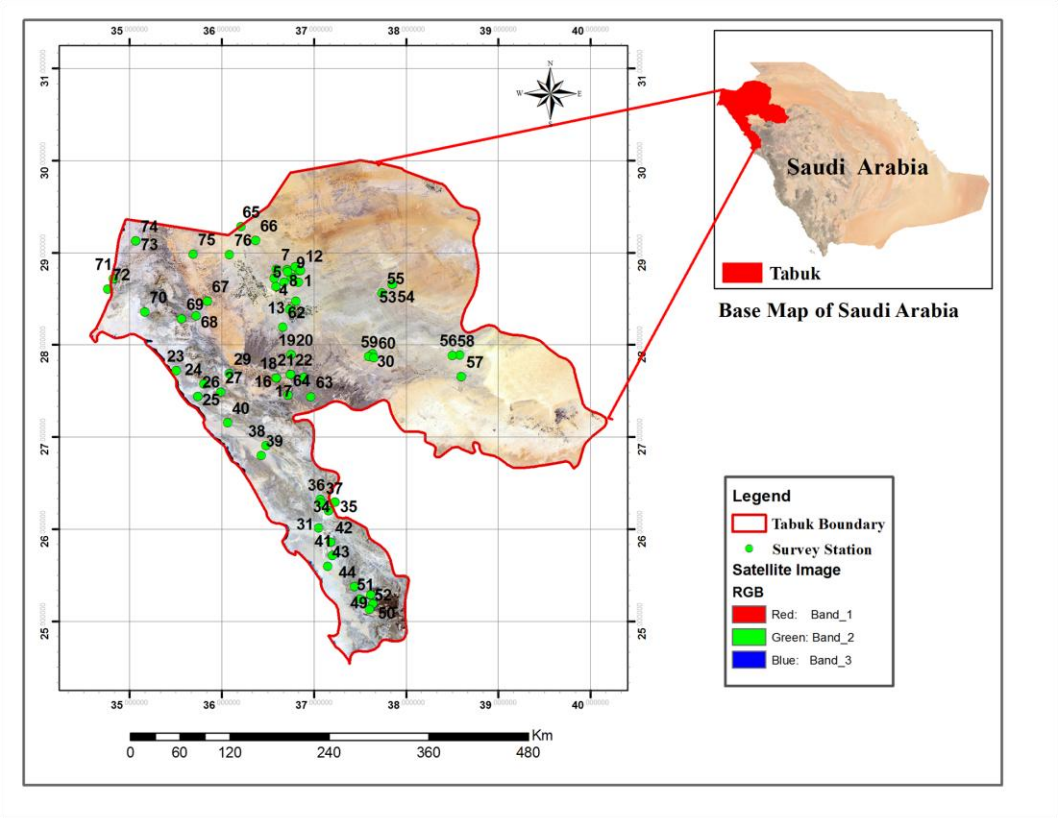

Fig. (1): Map of Saudi Arabia showing Tabuk region and the investigated sites.

Discussion

It is well known that zooplankton is common in the pelagic and littoral regions of ponds, lakes, large rivers, and oceans. In freshwater, these assemblages are dominated by the rotifers (Wallace and Snell, 1991) and two groups of micro crustaceans – the cladocerans (Dodson and Frey, 1991) and the copepods (Williamson, 1991). The littoral and benthic regions of freshwater characteristically hold large numbers of the divers and ancient micro crustaceans, the ostracods (Delmore, 1991). Zooplankton species tend to have wide geographic distributions (Carter et al., 1980 and Shurin et al., 2000).

The present investigation indicated that 38 taxa were recorded in the studied 76 sites at Tabuk region. Obuid-Allah (2000) studied zooplankton communities at Tabuk city; Saudi Arabia depending on 28 samples, recorded 24 taxa only. The increased number of taxa in the present study compared with that of Obuid-Allah (2000) is mostly due to that the present study covered the entire region as well as a variety of habitats that included virgin sites but that of Obuid-Allah (2000) was restricted in Tabuk city only. Aloufi and Obuid-Allah (2014) studied communities of zooplankton inhabiting 42 sites of inland waters of Al-madinah almonawwarah region; Saudi Arabia recorded 28 taxa. The increased number of taxa in the present study compared with that of Aloufi and Obuid-Allah (2014) may be due to differences in the studied habitats and differences in the number of the investigated sites.

In the present study, insects and crustaceans each of them was represented by 18 taxa and each one constituted 47% of the total taxa collected. The water mites and rotifers came in the second order where each of them constituted 3% of the total taxa collected. Obuid-Allah (2000) worked on the same region indicated that aquatic insects constituted the highest percentage of occurrence (93%) in all samples collected, ostracods (82%), copepods (57%), cladocerans (39%), rotifers (32%) and Anostraca (18%). He also noticed, at site (6) where he studied the density of different taxa during 11 months, that copepods dominated other taxa where they constituted 46% of the total catch during the period of study. Aloufi and Obuid-Allah (2014) studied communities of zooplankton inhabiting of inland waters of Al-madinah almonawwarah region; Saudi Arabia recorded that insects were represented by 12 taxa constituting 43% of the total taxa collected and crustaceans were represented by 14

taxa constituting 50% of the total taxa collected. Also, they noticed that water mites and rotifers came in the second order where each of them constituted 4% of the total taxa collected. Al-Asgah et al. (1989) prepared a list of zooplankton species in Saudi Arabia recorded 9 species of zooplankton which belong to cyclopoid copepods (2 species), Rotifera (5 species) and Cladocera (One species). Other studies in Saudi Arabia included that of Siddiqui and Al-Harbi (1995) on Wadi Hanifah stream at Alryadh region, examined 15 sampling stations along this stream concluded that the invertebrate fauna was generally poor. They noticed that insects were few and were recorded mainly from the lakes; Odonata were recorded at 5 stations, Diptera and Coleoptera were recorded at one station while Hemiptera at 2 stations. Similarly, Crustacea (Ostracoda and Copepoda) were poorly represented; being recorded at 7 stations while Rotifera were recorded from 10 stations. Also, the study of Al-Ghanim (2012) on the same Wadi (Wadi Hanifah) recorded 19 taxa in this stream. He indicated that Protozoa was the abundant group and that the reduction of zooplankton in this wadi may be affected by sewage and other domestic pollutant discharged in it. Abd El-Wakeil and Al-Thomali (2013) studied the aquatic macro invertebrates inhabiting Wadi Al-Arj, Taif, Kingdom of Saudi Arabia. They recorded 20 taxa belong to three phyla; Annelida, Arthropoda and Mollusca. Compared to the above-mentioned investigations carried out in Saudi Arabia, the present invertebrate fauna recorded at Tabuk region appeared richer. This richness may be due to the following main causes: 1- The present study covered a wide scale of the region as well as a variety of habitats that included virgin sites. 2-The water quality which is relatively cleaner than that of Wadi Hanifah and Wadi Al-Arj streams whose water sources are sewage effluents, agricultural investigation runoff and pumped shallow ground water. 3-One of the studied wades (Wadi Hanifah contains 7 introduced fish species and 22 species of migratory birds which may predate on the invertebrate communities and reduce them while at Tabuk region, no fish fauna were recorded except few sites (Sites 38, 39 and 57) and the recorded migratory birds were few in numbers. 4-The water current in the streams makes them unsuitable habitat for the development of rich zooplankton while Tabuk sites are mostly stagnant water bodies which promote rich zooplankton. This result concerning the effect of rapid water current on zooplankton was recorded by several authors like Rzoska (1976), Fernando (1980), Obuid-Allah (1987) and El-Shimy and Obuid-Allah (1992).

The present study indicated that among taxa collected, Family Chironomidae (Insecta) was widely distributed in the region. Depending on the criteria mentioned in the study, it was the only constant taxon since it was recorded in more than 50% of the collected samples. This result agrees with that recorded by Obuid-Allah (2000) who studied the same region and indicated that there was a marked distribution of aquatic insects belonging to family Chironomidae in the samples collected from all studied sites; where it was recorded in 50% of the samples. On the other hand he noticed that ostracods and dipterans' larvae "Culicidae" represented the constant taxa in his study. Aloufi and Obuid-Allah (2014) noticed that the constant taxa at Al-Madinah region were represented by 5 taxa namely: Calanoida (71%), Ostracoda (62%), *Moina micrura* (60%), Diptera pupae (57%), and Cyclopoida (52%). Aston (1973) observed that genus *Chironomus* which belong to family Chironomidae usually forms the second abundant genus in rivers receiving organic pollution. Hynes (1960) and Brinkhurst (1965) indicated that *Chironomus* is cosmopolitan in distribution. Aston (1973) accounted for this abundance due to its ability to colonize low oxygen concentration waters due to its ability to oxidize the mud on the river bottom to produce hemoglobin and its tolerance to toxic gases.

In the present study, the accessory taxa included 4 taxa namely: Ostracods, diptera pupae, Cyclopoida (Copepoda) and culicid larvae. Obuid-Allah (2000) indicated that the accessory taxa included 8 taxa namely: Hemiptera nymphs (Pleidae), dipterans' larvae (Chironomidae and Ephydridae), diptera pupae, Ephemeroptera nymphs (Siphlonuridae), crustacean copepods (Calanoida and Cyclopoida) and Rotifera.

Concerning grouping of the investigated sites into six groups namely, permanent lakes, temporary ponds, streams, wades, springs and wells and reservoirs. The results indicated that temporary ponds and permanent lakes recorded the richest number of taxa. This richness may be due to that both of them constituted the majority of sites investigated as well as the suitability of their physicochemical characteristics for taxa. Also organisms are not subjected for desiccation in case of permanent lakes and predation by fish or other predators. It was noticed in the study that streams and springs harbored the least number of taxa. This poverty of taxa is justified by the nature of the sites since streams have high speed drifted new water which gives no chance for the association of true zooplankton taxa. Also they are highly impacted by man and the passage of one of them (Al-Deesah) is used as a way for transportation. Springs investigated also share some reasons for their poverty in taxa with streams since they have high speed drifted new water. Also one stream investigated is a hot one.

Taking in consideration, other results conducted in different countries. Singh et al. (2012) studied the diversity of zooplankton in MahendraNath pond-India; he noticed that the population of zooplankton consisted of rotifers, copepods and cladocerans. Farshad and Venkataramana (2012) studied zooplankton diversity in India; they noticed that zooplankton was made up of Rotifera (62%), Copepoda (12.00%), Cladocera (19.50%), Diptera

(4.00%) and Nematoda (4.50%). Kumar et al. (2011) studied the seasonal variations in zooplankton diversity in India and they indicated that in all 76 zooplankton species recorded belonged to Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda. Out of 76 species, 9 species belonged to Protozoa, 37 species to Rotifera, 15 species to Cladocera, 12 species to Copepoda and only 3 species to Ostracoda. Srivastava (2013) studied the monthly variations of zooplankton in a freshwater body, Ramgarh lake, Gorakhpur, U.P., he noticed that the zooplanktons were represented by three groups of organisms in order Crustacea>Rotifera>Protozoa.
Abdulgabar (2013) studied Zooplankton communities in Al-Ibrahimiyah canal at Assiut, Egypt; she recorded that the collection comprised 73 taxa including 5 groups. Rotifera was the most important group (23 taxa belonging to, at least, 16 genera), Cladocera (18 species), Copepoda (10 species adult species, Nauplius larvae and Copepodite stages), the group of the "other groups" (12 taxa: 10 taxa of insects belonging to 7 orders, Nematoda and the" spiders and mites") and Ostracoda (8 species).

The presence of zooplankton organisms in the inland waters of Tabuk region despite of its arid nature and the fact that all sites investigated were mainly formed by rain and were not connected to any constant source of water may raise a question about the source of these organisms. Dodson and Frey (1991), Delorme (1991), Wallace and Snell (1991) and Williamson (1991) indicated that the majority of freshwater zooplankton have a strong potential for dispersal and that most species so far investigated are capable of forming resting eggs which are resistant to desiccation, freezing and digestive enzymes and may be brought from time to time on water birds or by wind or floods. Furthermore, many species are parthenogenesis which allows single females to reproduce. Nevertheless, the cosmopolitan distribution of many species has been questioned by Frey (1982) and newly-discovered exotics are allowing detailed discovery of the dispersal process (Havel et al., 1995).

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