A PRELIMINARY STUDY ON AQUATIC INSECT DIVERSITY AND ABUNDANCE IN RELATION TO FLUCTUATING PHYSIOCHEMICAL PARAMETERS OF AN ARTIFICIAL POND

Sabina Noor*, Nosheen Rafiq, Palwasha Akbar,
Saima Zehri, Sana Wali & Farzana Shahwani
Department of Zoology,
Sardar Bahadur Khan Women University,
87300 Quetta, Pakistan.
*Corresponding author: *sabina.noor15@yahoo.com*

ABSTRACT

This preliminary study was conducted from April to October 2019, and hold the first account to outline the diversity of aquatic insects with influence to the fluctuating physiochemical parameters in the pond of Sardar Bahadur Khan Women's University Quetta. The collection of 722 individuals in total presented four orders (Hemiptera, Ephemeroptera, Diptera and Odonata) and seven families. These individuals were labeled to generic level as *Gerris* sp., *Notonecta* sp., *Anopheles* sp., *Thaumalae* sp., *Sympetrum* sp., *Orthetrum* sp. and *Heptagenia* sp. Shannon-Weinner diversity and Simpson's diversity index revealed greater values for back-swimmers and mayflies (*Notonecta* and *Heptagenia* sp.). Additionally, Margalef's richness index was also recorded highest (1.163) for backs-swimmers. Amongst physiochemical parameters, water temperature was ordinated in Gaussian's species packing model. This ordination illustrated wider curve for *Notonecta* sp. and narrower curve for *Anopheles* sp., suggesting the maximum and minimum tolerance (temperature) range for these species in this specific pond community. Water pH of the pond also altered slightly and ranged from 9.13-10.3 during April to August. As of the total dissolve solids (TDS), this study observed a raised from 253.16 mg/L to 432.11 mg/L till the end. Since aquatic insects play vigorous role in the stability of aquatic ecosystems, more relevant studies are required to be conducted to evaluate the broader range of these insects.

Keywords: Aquatic, diversity, abundance, tolerance, physio-chemical

ABSTRAK

Kajian awalan ini telah dijalankan dari April hingga Oktober 2019 bermatlamatkan untuk mengkaji kepelbagaian spesies serangga akuatik yang dipengaruhi oleh parameter fisiokimia kolam di Sardar Bahadur Khan Women's University Quetta, Pakistan. Sejumlah 722 individu telah dikumpulkan yang merangkumi empat order (Hemiptera, Ephemeroptera, Diptera dan Odonata) dan merujuk tujuh famili. Kesemua individu telah dicamkan hingga ke peringkat genus iaitu *Gerris* sp., *Notonecta* sp., *Anopheles* sp., *Thaumalae* sp., *Sympetrum* sp., *Orthetrum* sp. dan *Heptagenia* sp. Indeks Kepelbagaian Shannon-Weinner dan Indeks Kepelbagaian Simpson's telah menunjukkan nilai yang tinggi untuk *back-swimmers* dan *mayflies* (*Notonecta* sp. dan *Heptagenia* sp.). Sebagai tambahan, Indeks Kepelbagaian Margalef telah merekodkan nilai tertinggi (1.163) pada *backs-swimmers.* Di antara parameter fisiokimia, suhu air telah diordinasikan oleh Gaussian's *species packing model*. Ordinasi telah melakarkan lengkungan yang lebar untuk *Notonecta* sp. manakala lengkungan sempit untuk *Anopheles* sp., yang mencadangkan nilai toleransi maksimum dan minimum (suhu) untuk spesies di komuniti spesifik di kolam. pH air di kolam sedikit berubah pada lingkungan 9.13-10.3 pada April hingga Ogos. Jumlah bahan larut (TDS) dalam kajian ini meningkat dari 253.16 mg/L to 432.11 mg/L hingga ke hujungnya. Memandangkan serangga akuatik memainkan peranan yang penting dalam menstabilkan ekosistem akuatik, oleh itu pelbagai kajian amat penting dijalankan dalam menilai dengan lebih terperinci ke atas spesies ini.

Kata kunci Akuatik, kepelbagaian, kelimpahan, toleransi, fisiokimia

INTRODUCTION

Lesser than one percent of the Earth's surface is covered by freshwater, but harbors more than six percent of all insect species (Dijkstra et al. 2014). Assessing nearly 100,000 aquatic species under 13 orders spends one or more of their life stages in freshwater bodies, nonetheless majority of which are terrestrial dwellers in their adult stages (Dudgeon et al. 2006). Freshwater ecosystems are grouped into lentic and lotic water, such division is useful for indicating physical and biological differences. However, habitat diversity can vary tremendously with in these two broad categories and some of the same taxa might be found in both habitats (Merritt & Wallace 2009). In either of lotic or lentic ecosystems, the trophic status of aquatic insects covers all categories mainly as primary consumers, predators, scavengers, parasitoids, pollinators and significantly as a biological control agent in contradiction of disease-carrying mosquitoes (Mohanraj et al.2012; Irshad et al. 2015).

With the current rate of anthropogenic activities and climate change, freshwater habitats are reported the most threatened on earth, hence the investigation of aquatic insects is therefore timely (Abdul-Aziz & Mohamed 2019; Ghani et al. 2016; Heino 2009; Hering et al. 2009; Vörösmarty et al. 2010). Freshwater habitats are highly diverse and include ponds, lakes, springs, streams, rivers, wetlands, reservoirs and ditches, and the drift pattern of the stream insects are different between day and night ('Amila & Suhaila 2019). Around the world ponds inhabit diversified fauna of aquatic insects (Merritt &Cummins 1996), There are 11 order of aquatic insects in which Ephemeroptera, Odonata, Diptera, Trichoptera, Hemiptera, Megaloptera, Neuroptera, Coleoptera and Hymenoptera are widely found around the globe in ponds (Voshell 2002).

Most significantly throughout the world aquatic insects are acknowledged as a bio-indicators of varying water quality and their capability of tolerance contribute through various actions in order to enhance the quality of ecosystem (Andersen & Weir 2004; Arimoro & Ikomi 2008; Das & Gupta 2010). The physio-chemical factors of water include the air and water temperature, water level fluctuation, pH, alkalinity, total dissolve solids (TDS), dissolved oxygen concentrations (Popoola et al. 2019). These factors alternatively determine the type and density of insects inhabiting that particular water body and their rate of metabolism is altered by the water temperature that directly or indirectly increase or decrease the growth of insect, from egg to adult (Hepp et al. 2010).

Limited work has been reported in Pakistan with reference to the diversity of aquatic insects in ponds. Since no such documentation has been reported as the diversity of aquatic insects in relation with fluctuating physio-chemical parameters of a pond in Balochistan, this study will mark as first amongst all.

MATERIALS AND METHODS

Sampling Area and Duration

The current study was performed to evaluate the diversity of the aquatic insects relative to the physio-chemical parameters of a pond during April-October 2019. For the current study, a pond located at (30°11'29"N latitude, 66°57'34"E longitude and 1576" altitude) in SBK Women's University Quetta campus was selected (Figure 1). It is an artificial pond created to sustain moderate water supply to nearby or surrounded campus vegetation. This pond was created a decade ago and since then it has been observed to nurture and support various aquatic insects.

Figure 1. An artificial Pond located at the campus of SBKWUQ

Physio-chemical Parameters and Insect Sampling

The physio-chemical parameters of this study include pH, water temperature, and total dissolved solids (TDS). For the physio-chemical variables, six replicates were averaged to retrieve data for water temperature (via Thermco ACC2457S), measured at the pond, whereas pH and TDS (Jenway-3540 pH+conductivity meter) were evaluated (under 30 minutes of sampling) in the laboratory of SBK Women's University Quetta. Insects sampling were made with the help of a sieving trap, open mouth container fills (1500 ml), and hand net (100 cm in diameter, 1mm mesh size) for capturing the adults. Each sampling technique was replicated for six times (later on the data was averaged to one). Intended for each sampling, six underwater sweeps were done and six open mouth containers were filled with sample water. To check for the presence of aquatic insects, the water sample was divided into 6 beakers (500 ml) equally, for visualization/identification and total count. In later months adults stages of encountered aquatic insects around the pond were counted within a radius of 5-10 meters.

Species Identification

After collection samples were brought to the entomological laboratory and individuals were preserved in 70% alcohol in test tube (115 mm) for identification. Each individual was provided a voucher number and name (up to generic level). Species identification was achieved via dissecting microscope with Leica M50 (25/40x magnification) and through pertaining literature available online (www.macroinvertebrates.org; bugguide.net) as well as from keys provided by Distant (1906;1907;1911; 1916; 1918).

Data Analysis

The averaged tri-monthly data was organized and Paleontological Statistics Ver: 4.0 (PAST) was utilized to analyzed the data. Species diversity indices was derived. Amongst these indices, Shannon–Wiener diversity index is a measure used by ecologists when a system contains too many individuals for each to be identified and examined. The index (D) is the ratio of the number of species to their importance values (e.g. biomass or productivity) within a trophic level or community (Allaby 2020). Simpson's index (D) is quantified as the two randomly selected individuals belong to two different species/categories. The value of this index ranges between 0 and 1, the greater the value, the greater the sample diversity (Jost 2006). Shannon's evenness is a measure of how similar the abundances of different species/categories are in a community. This ranges from 0 to 1, where values close to zero, specifies that most of the individuals belongs to one or a few species/categories. Evenness values close to one, indicates that each species/categories consists of the similar number of individuals. Fisher's alpha is a parametric index of diversity that assumes that the abundance of species follows the log series distribution (Taylor et al. 1976). Species packing (Gaussians) was obtained in order to relate the optimum temperature of pond water with the species tolerance range and abundance.

RESULTS

The current preliminary study was documented to determine the diversity of aquatic insects in the pond of SBK Women University relative to the fluctuating physio-chemical parameters of water. We collected a total of 722 individuals insect in the pond during the study period. The encountered individuals were identified and arranged into four orders i-e Hemiptera, Odonata, Diptera and Ephemeroptera and under six families particularly Gerridae, Notonectidae, Culicidae, Thaumaleidae, Libellulidae and Heptagenidae (Table 1).

Table 1. Summarized data of the collected species at the pond

S.No	Species	Illustration	Families	Order
1	*Gerris* sp.	Plate I; figure A	Gerridae	Hemiptera
2	*Notonecta* sp.	Plate I; figure C	Notonectidae	Hemiptera
3	*Anopheles* sp.	Plate I; figure B	Culicidae	Diptera
4	*Thaumalea* sp.	Plate I; figure D	Thaumaleidae	Diptera
5	*Orthetrum* sp.	Plate II, figure G	Libellulidae	Odonata
6	*Sympetrum* sp.	Plate II; figure F	Libellulidae	Odonata
7	*Heptagenia* sp.	Plate II; figure E	Heptagenidae	Ephemeroptera

For the physio-chemical parameters of the pond, water temperature fluctuated constantly and ranged between 19.6°C to 23.18°C, with lowest temperature recorded in April (19.6°C) and the highest in August 30°C (Table 2). There was a gradual increase of water temperature from April-August and decrease from August till October. With the temperature variation, pH of the water also altered slightly and ranged from 9.13-10.3 during April to August, respectively. As of the TDS was also observed raised from 253.16 mg/L to 432.11 mg/L till the end of the study.

Table 2. Physio-chemical parameter of the pond during the study

Months	Water temperature °C	pH of water	TDS (mg/L)
April	19.6	9.13	253.16
May	26.25	9.23	326.34
June	29.7	9.36	372.56
July	29.23	9.51	411.03
August	28.4	10.1	428.21
September	25.15	10.01	407.61
October	23.18	10.3	432.11

The biodiversity of the pond was attributed to the presence of seven species, the highest frequency of which recorded in the month of October (Table 3). This was because of 160 individuals of imago/spinner of *Heptagenia* sp. Plate II; Figure E) swarm the pond. In the earlier months of the study, mayfly naiads were less encountered as it stayed in the depth of the pond. The majority number of individuals were encountered in October with the averaged water temperature of 23.18°C and pH of 10.3. The second highest frequency of pond diversity was derived by back-swimmers constantly encountered during the study. The largest number of *Notonecta* species (Plate I; Figure C) were gathered in June at 29.7°C, 9.36 pH. The immatures of back-swimmers were dominant during April-June, while July-October the pond was prevailed mostly by adults. Another member from Hemiptera was adults of *Gerris* sp. (Plate I; Figure A) encountered on pond. The maximum number raised to 22 individuals in August with average water temperature of 28.4°C. As compare to back-swimmer, water strider was found in August-October (Table 3). Odonata was noticeable by obtaining two type of naiads in August, later on which were identified into *Orthetrum* sp. and *Sympetrum* sp. (Plate II; Figure F & G). The exuviae of last nymphal instar from two species were encountered on the walls of pond as well, from which the adults emerged. Order Diptera was obtained with the presence of 50 mosquitoes (individuals) identified as *Anopheles species* (Plate I; Figure B) and 17 individuals of *Thaumalae* sp. (Plate I; Figure D) detected from July-October.

Table 3. Averaged bi-monthly collection data of aquatic insects at the pond

Months	Back-Swimmers	Mosquitoes	Dragonflies	Water Striders	Mayflies	Crane Flies	Total
April	43	0	0	0	39	0	43
May	23	0	0	0	16	0	23
June	63	0	0	0	11	0	73
July	15	15	0	0	30	2	62
August	17	25	2	15	70	4	133
September	10	10	07	22	84	3	152
October	03	0	20	5	160	8	236
Total	174	50	29	42	410	17	722

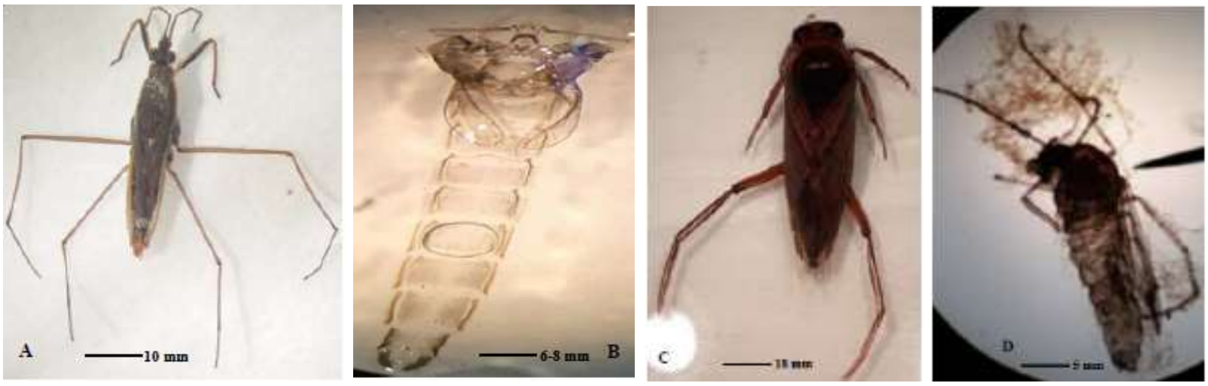

Plate I. Figure A) G*erris species;* B) *Anopheles species; C) Notonecta species; D) Thaumalea species*

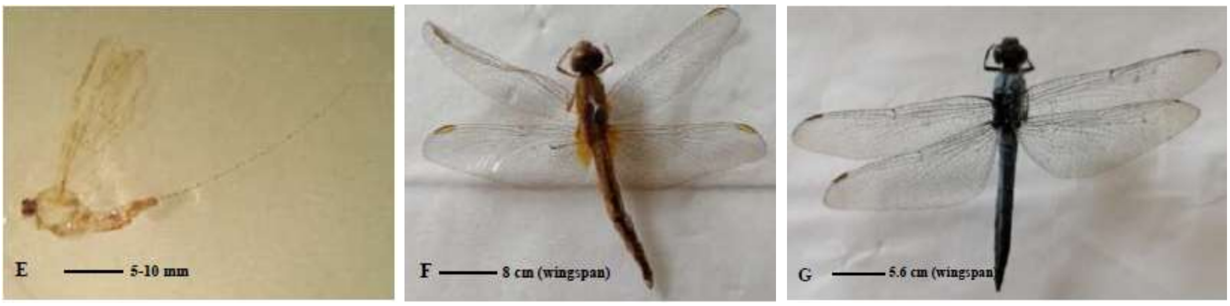

Plate II. Figure E) *Heptagenia species; F) Sympetrum species; G) Orthetrum species*

The diversity indices evaluated for the aquatic insect's community at the pond during six months (Table 4) showed highest Shannon-Weinner index value for back-swimmers (1.653) and mayflies (1.633) as shown in Figure 2. This suggests that both back-swimmers and mayflies had the same frequency of individuals encountered each month. Interesting to the fact that Margalef's richness index was also recorded highest (1.163) for backs-swimmers.

Simpson's diversity index also revealed greater values for back-swimmers and mayflies as 0.769 and 0.759, respectively. Diversity indices plot against the Fisher's alpha shows back-swimmers (shown in red) on the highest trend followed by mayflies (shown in purple) (Figure 3). Shannon's Evenness showed greater values for mosquitoes (0.933) followed by crane flies (0.875) and Water striders (0.870). Their increased rates showed that these taxa were highly uneven in this community of aquatic insects (Figure 4).

Table 4. Diversity indices of aquatic insects recorded for six months at the pond

Diversity Indices	**Back-Swimmers**	**Mosquitoes**	**Dragonflies**	**Water Striders**	**Mayflies**	**Crane Flies**
Individuals	174	50	29	42	410	17
Simpson's Diversity index	0.7698	0.62	0.4614	0.5839	0.7599	0.6782
Shannon-Weinner diversity index	1.653	1.03	0.7838	0.9598	1.633	1.253
Shannon Evenness	0.7464	0.9334	0.7299	0.8704	0.731	0.8752
Margalef's richness index	1.163	0.5112	0.5939	0.5351	0.9973	1.059
Fisher's_alpha	1.462	0.7006	0.8404	0.7395	1.199	1.649

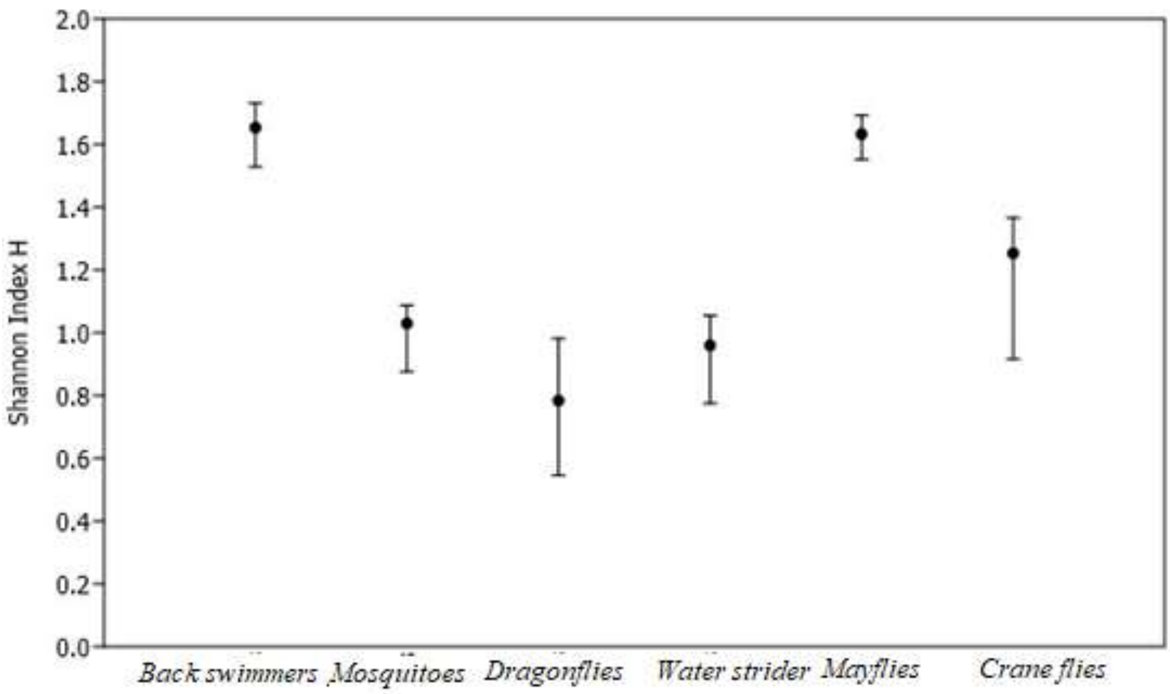

Figure 2. Shannon-Weinner diversity indices among the taxa of pond aquatic insects

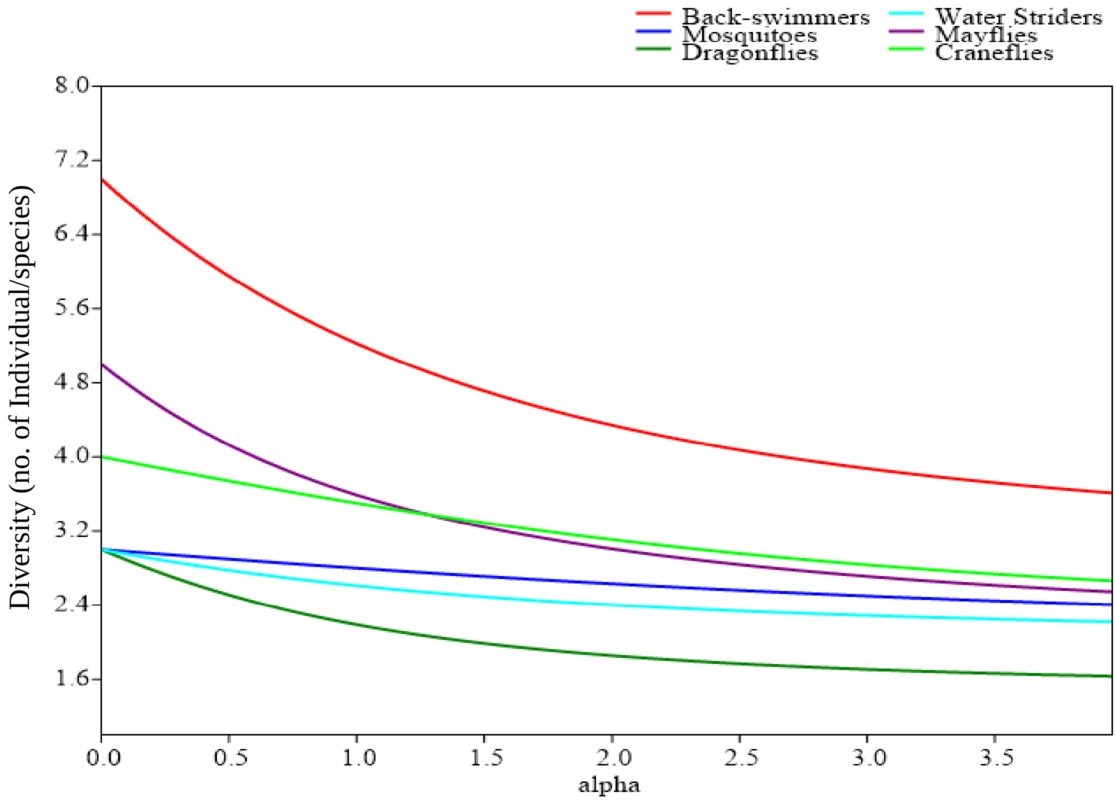

Figure 3. Diversity indices against Fisher's alpha plotted for aquatic insects encountered at the pond

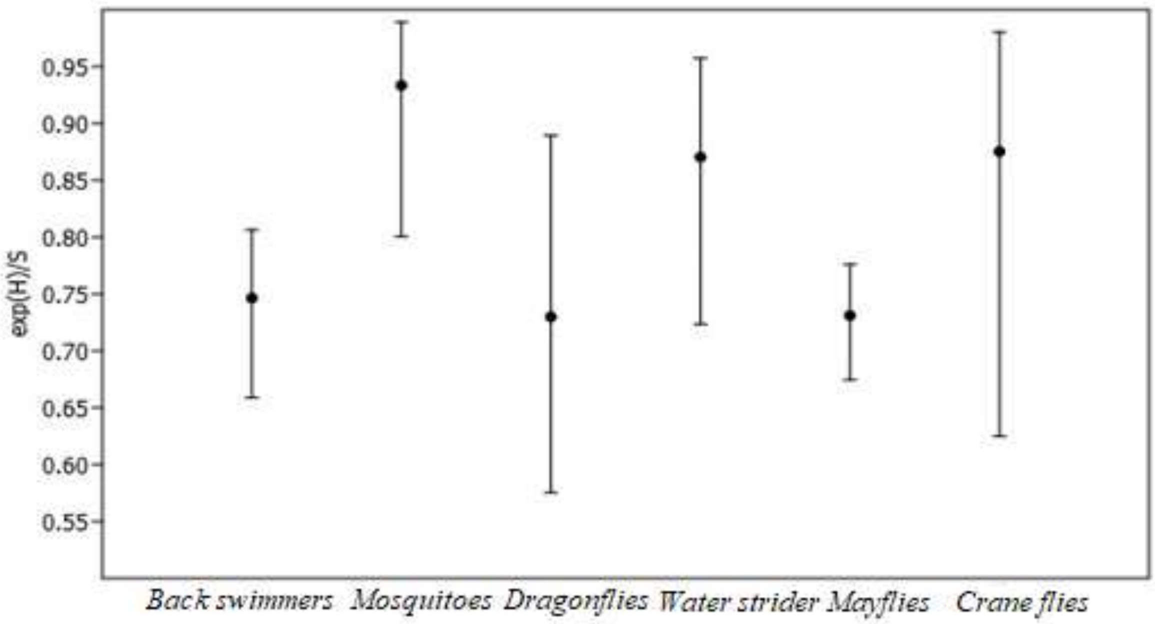

Figure 4. Shannon's Evenness calculated for the six taxa showing greater evenness for mosquitoes, crane flies and water striders

Gaussian's species packing model was ordinated for water temperature (as an environmental factor) and species abundance (month-wise). This model resulted in a highest optimum temperature for mosquitoes to be 28°C with a tolerance rate of 1.46°C and prospects about 25 individuals could exist at this temperature among the total population (mosquitoes) (Table 5). The wider curve of species packing model was ordinated for *Heptagenia* sp. as about 160 individuals of mayflies could exist at an optimum temperature of 24.8°C and would tolerate to just 2.82°C (Figure 5). However, back-swimmers showed linear response to temperature in the species packing curve with an optimum of 26.2°C by 63 individuals (36%). For all the taxa the optimum temperature ranged between 24-28°C at the pond during April to October. This suggested that almost half or more (%) population of the encountered taxa could exist at their specific optimum temperature while can tolerate to 1-2.5°C in the pond. The overall monthly abundance of aquatic insects at the pond is plotted in Figure 6.

Table 5. Species packing (Gaussian) values of abundance against the water temperature of pond

Water Temperature	Back-Swimmers	Mosquitoes	Dragonflies	Water Striders	Mayflies	Crane Flies
Optimum	26.2°C	28°C	24°C	26°C	24.8°C	25.4°C
Tolerance	4.08478	1.46914	1.45529	1.83753	2.82019	2.48377
Maximum	63	25	20	22	160	8

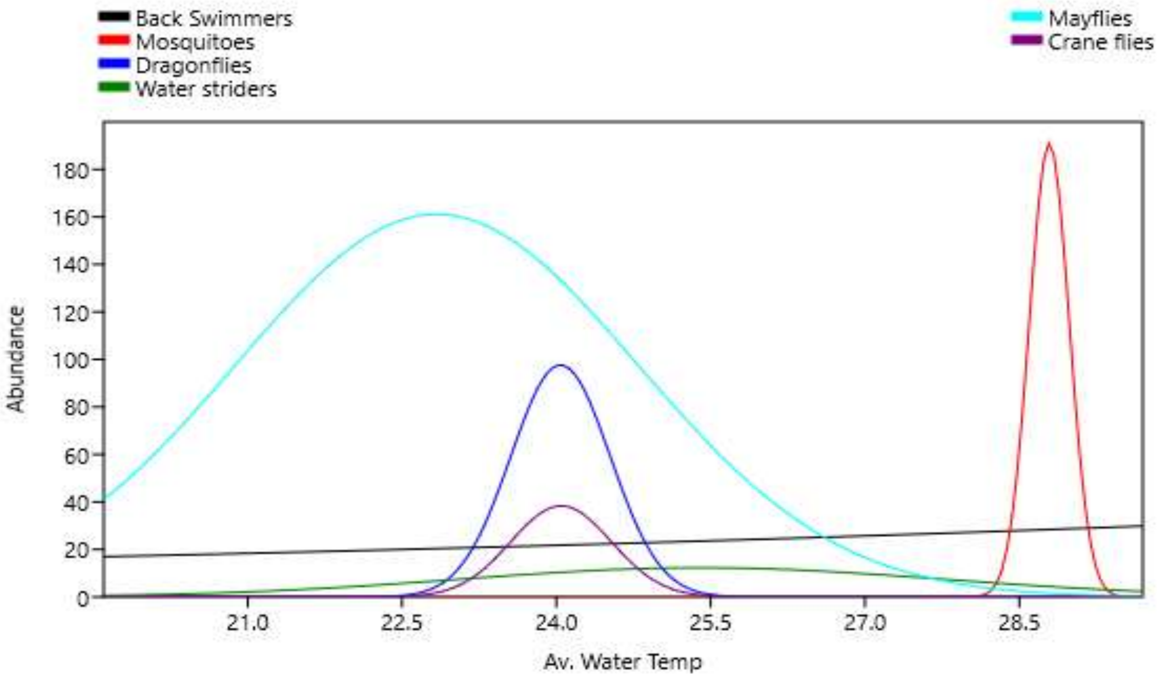

Figure 5. Gaussian's species packing curves ordinated for the pond aquatic insects against temperature

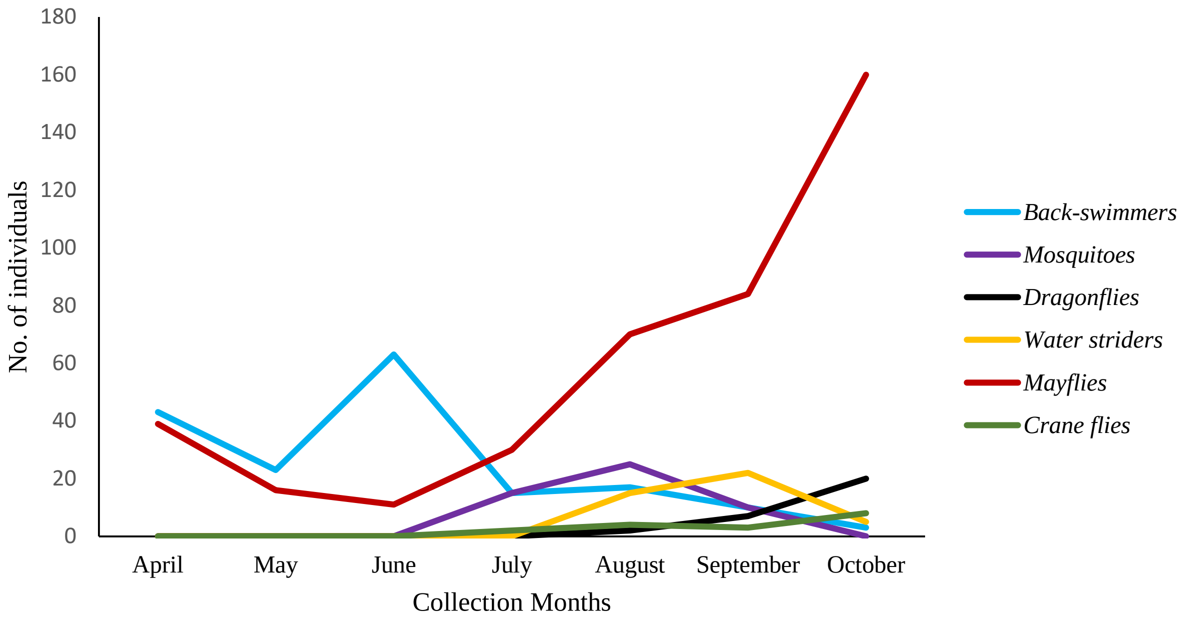

Figure 6. Abundance of aquatic insects during the study period in the Pond

DISCUSSION

The present study was attempted to describe the preliminary report on the aquatic insect's diversity of a pond at SBK Women's University Quetta campus. A total of 722 individuals were encountered at the pond during seven months, later of which were identified into seven species belonging to four orders under six families. The distinctive orders namely accounted as Hemiptera with representatives as *Gerris* sp. and *Notonecta* sp. (174, 42 individuals, respectively); Ephemeroptera represented by *Heptagenia* sp. (410 individuals); Odonata represented by *Orthetrum* sp. and *Sympetrum* sp. (29 individuals); Diptera represented by *Anopheles* sp. and *Thaumalea* sp. (50, 17). Similar studies of pond aquatic insect diversity reveal the presence of numerous orders at a single community such as Hemiptera, Odonata, Coleoptera, Ephemeroptera, Diptera, Trichoptera, Plecoptera (Chattha et al. 2018; Dijkstra et al. 2014; Jarjees et al. 2019; Majumder et al. 2013; Nasiruddin et al. 2014). Notonectidae and Gerridae are documented as the most common families that inhabit the pond ecosystem (Chattha et al. 2018; Das & Gupta 2010), both of these families were also encountered in this study represented by *Notonecta* and *Gerris* sp. *Notonecta* sp. prefers small habitats exclusively ponds with clay substrate and inadequate vegetation (Klementová et al. 2015). Diptera in this study was represented by *Anopheles* and *Thaumalea* sp., for which researchers describe these individuals being profound of stagnant water (Dijkstra et al. 2014; Saeidi & Vatandost 2018). Most notable acquainted odonatofauna individuals are profound of inhabiting good water quality reservoirs such as rivers, streams and canals. However, exclusively the odonate populations can be accounted for vulnerability and threat due to water pollution and recreational activities recounted from countries, like Malaysia (Abdul-Aziz & Mohamed 2019). In the present study *Heptagenia* sp. was the most abundant individual in this pond community, implicating that this order is exclusive in many similar studies (Dijkstra et al. 2014; Ghani et al. 2016).

The physio-chemical variables of pond water included water temperature, pH and TDS. Studies suggests that various physio-chemical parameters of water quality influence the diversity, density and distribution of aquatic insects in a particular community and these variables are interdependent (Ghani et al. 2016; Purkayastha & Gupta 2013). During the study water temperature of the pond varied between 19.6-29.7°C and the pH of water ranged from 9.1-10.3 implying the high alkalinity of pond water. Increased pH of the pond water is due to the photosynthesis activity responded by the dense algal blooms (Wurts & Durborow 1992). Whereas, studies prove that taxa richness, density and diversity improve as the pH of water bodies inclines (Scheibler et al. 2014; Prommi & Payakka 2015). Conversely, few Ephemeropterans, particularly the *Heptagenia* sp. is described to be negatively associated with higher pH (Ghani et al. 2016). Diversity indices depicted higher Shannon-Weinner diversity index, Sampson's Dominance index and Margalef's richness index for back-swimmers and mayflies. These two species are most common and dominant among pond communities and persistent in both man made as well as in artificial ponds (Whiteson 2009). Ultimately, higher Shannon's Evenness values for mosquitoes, crane flies and water striders illustrated their irregularity in presence/abundance at the pond. For two group of insects such as surface hunters and divers, ponds, lakes and stagnant water bodies serves the most common habitats (Vasantkumar & Roopa 2014). Logically, this is proven that the captured adults of these species in this study were migratory as well as surface dwellers (Whiteson 2009).

Gaussian's species packing model was executed between the monthly abundance of aquatic insects and temperature as an environmental variable. The wider curve of which was ordinated for mayflies and narrower for mosquitoes. The results were apprehended to be similar as variant curves of Gaussian's model showed that each species behaves differently, with their own optimum, maximum and tolerance range towards that environmental variable (Fernández-Gómez et al. 2011).

CONCLUSION

This study resulted in the collection of a total 722 individuals of aquatic insects describes under four orders Hemiptera, Diptera, Odonata and Ephemeroptera. The number of aquatic insect species and their abundance varied monthly in the pond during the study period with physio-chemical parameters of water. Mayflies and back-swimmers were the most abundant and common group in this pond community. The results reveal that Quetta region might have diverse and rich aquatic insect's fauna because of its moderate temperature. However, this study was accomplished on a smaller scale, scientific results approves as aquatic insects have both beneficial and harmful impacts on the environment, more relevant studies are needed to be conducted on larger scale to explore the aquatic insect fauna in this bio-diverse region.

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