Article

Effect of salinity gradients on species composition of Odonata naiads

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Abstract
In present study the relationship between salinity gradients of various water bodies and inhabiting Odonata naiads was studied. Naiads, being a popular group of water pollution indicators, were studied. Totally 35 sites were surveyed for collection of naiads and water samples were taken from each positive site. Eight factors viz. Electrical Conductivity (Ec), Calcium +Magnesium (Ca+Mg), Sodium (Na+), Carbonates (Carb), Bicarbonates (Bc), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) were studied for each water sample. Interesting results were obtained both for Anisoptera and Zygoptera species. Among dragonflies, genus *Crocothemis* of family Libellulidae appeared to be resistant while Genus *Gomphidia* and *Sympetrum* of families Gomphidae and Libellulidae were observed to be affected by variations in salinity gradients of waters of different sites. However in case of damselflies Genus *Ischnura of* family Ceonagrionidae and genus *Pseudagrion* of family Ceonagrionidae were observed to be adaptive followed by genus *Ceriagrion* of same family. As an overall conclusion, Anisopterous naiads were found more susceptible to salinity gradients than Zygoptera and thus can be better used in water salinity diagnoses studies.

Keywords salinity; chemical composition; Odonata; naiads.

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1 Introduction

Aquatic ecosystems are home for diverse groups of insects where they play different roles. They are important components of aquatic food chain by either feeding on aquatic plants, protozoans, algae, fish fries, mosquito larvae, tad poles, and minute crustaceans (Bhatti et al., 2014; Smith, 2005) or being fed by fishes, frogs, ducks and birds etc (Rafi et al., 2009; Din et al., 2013). They are also used as baits to catch fishes and to determine water quality (Zia et al., 2008; Zia, 2010). The lifestyle of aquatic insects required many adaptations including specialism in respiration, osmoregulation and motility. Aquatic insect fauna is thus interesting as well as ecologically and economically important (Smith, 2005).

Order Odonata is an important group of class Insecta that carries immense importance in terrestrial as well as aquatic ecosystems. They are one of the most intensively studied and focused groups in tropical research (Zia et al., 2011a; Zia, 2015). Strictly restricting to their role in aquatic habitats, it is worth mentioning that these environments remain incomplete without their presence. They provide variable services to humanity; some time as predators of biting pests, sometimes as indicator of drinking water quality (Silsby, 2001), some time to suppress development of disease carrying mosquitoe's larvae (Zia, 2009), some time as bio-control agents in crops (Zia, 2010) and bio-indicators of environmental disturbances (Zia et al., 2011b) and even sometimes as lures to catch fishes (Azam et al., 2015; Zia et al., 2009).

Anthropogenic activities are constantly affecting natural ecosystems all over the world (Azam et al., 2015). Among natural factors affected, salinity is a crucial factor that affects life of aquatic invertebrates directly as well as indirectly. Salinity can be outlined as a measure of the content of salts in water or soil. Although primary salinity is the outcome of natural activities like wind, weathering of rocks and rain that deposits salt over thousands of years. Yet, secondary salinity is the outcome of human activities. It takes place due to intensive clearing of land and by introducing shallow rooted plants as alternative to native deep-rooted plants with a view to use less water (Australia). Salinity in any form decrements dissolved oxygen that normally affects respiration of aquatic fauna. Freshwater creatures are likely to be suffered from lethal and sublethal effects of salinity as they are much sensitive to saline environments and can hardly maintain the osmotic balance required (Kulp et al., 2007; Soucek and Kennedy, 2005). Odonata naiads are directly affected by quality of water they are living in (Azam et al., 2015). Bancroft et al. (2007) defined salinity as a sublethal stressor and documented that it has a clear impact on predator-prey interactions of *Ischnura elegans* (Odonata: Zygoptera). Odonates are versatile insects that are found in almost every type of water body ranging from sweat waters of springs to acidic and brackish waters of desert lakes (Hannam, 1998; Din, 2012). According to Hudson and Berrill (1986), their eggs are relatively unaffected by low pH. Keeping in view the effects of salinity on aquatic invertebrates and capabilities of Odonata naiads to withstand brackish waters, we plan to study their species composition in relation to salinity levels of Potohar plateau in Punjab province of Pakistan.

2 Materials and Methods

2.1 Insect collection

Collection surveys to collect naiads of Odonata were carried out during active season (summer months) of the years 2011-12 in 35 localities of Potohar plateau (Punjab) Pakistan viz., District Rawalpindi: Ayub Park, Kahuta, Narr, Nara Mator, Mohra, Murree, Mandra, Kotli Sattyan, Chakian, Jatla, Dhoke Syedaan,Pind bhagwal, Athal colony; District Islamabad: Simly dam, Barakahu, Bobry, Rawaldam, Shadara; District Chakwal: Bhurpur, Chakwal, Ghurab dam, Ghabeer Nala, Thoha Mehram Khan, Wallana dam, Kattas, Chua Saidan Shah, Peer Nara; District Jhelum: Dina; District Attock: Fatehjang, Kheri Moorat, Qutbaal, Talian, Pindi gheb, Taja Bara, Shahpurdam. Specimens were recorded from variable habitats like ponds marshes, ditches, lakes, ephemeral pools, streams, rivers and springs (Fig. 1).

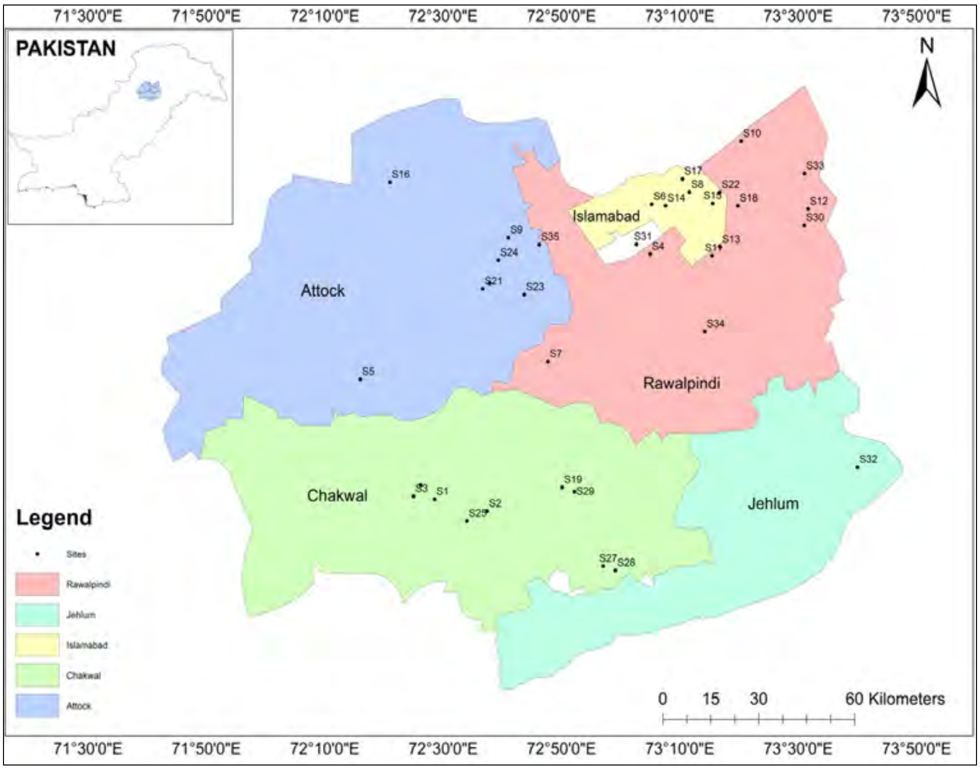

Fig. 1 Map showing surveyed localities to collect Odonata naiads.

2.2 Analysis for salinity profile

Water samples were collected from each surveyed locality. These samples were analyzed for salinity profile at Soil Fertility and Testing Laboratory, of Agriculture department, Rawalpindi by studying eight factors i.e. Electrical Conductivity (Ec), Calcium + Magnesium (Ca+Mg), Sodium (Na+), Carbonates (Carb), Bicarbonates (Bc), Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC).

2.3 Identification of specimens

Recorded naiads specimens were taxonomically identified at National Insect Museum, NARC Islamabad under Labomed sereoscope (CZM4-4X) following Hussain (1988), Khaliq et al. (1994) and Din (2012). Species confirmation was also taken through reference collection of Odonata naiads housed at museum.

2.4 Statistical analysis

All collected data were analyzed by using SPSS 16.0 (Statistical Package for Social Sciences) and grouping of all surveyed sites was done by Hierarchical Agglomerative Cluster Analysis (HACA) using Wards Method as a clustering technique.

3 Results and Discussion

The study conducted to compare relationship between species composition of Odonata naiads and salinity gradients brought forward very interesting results. The data (Table. 1) provides a very clear picture for any slight change in salinity profile affecting species diversity. A total of thirty three species of dragonflies and damselflies were recorded in this study, with details as indicated in Table 1.

Table 1 Salinity profile of studied sites in comparison to Odonata species recorded.

Site No.	Sites	Odonata Species	Ec	Ca+Mg	Na+	Carb	Bc	Chloride	SAR	RSC
S1	Peer Narra	*Crocothemis erythraea, Pantala flavescens, Selysiothemis nigra, Sympetrum fonscolumbei*	1.08	5.31	5.51	0	7.5	1.8	3.4	1.99
S2	Wallana dam	*Trithemis aurora, Trithemis festiva, Orthetrum chrysis*	0.64	4.12	2.34	0	5.1	1	1.63	0.98
S3	Ghurab Dam	*Crocothemis erythraea, Pantala flavescens, Selysiothemis nigra, Sympetrum fonscolumbei, Orthetrum chrysostigma luzonicum, Orthetrum taeniolatum, Ceriagrion coromandelianum*	0.83	4.41	3.95	0	6.7	1.2	2.66	2.29
S4	Ayub Park	*Crocothemis erythraea*	0.42	3.35	0.85	0	3.8	0.9	0.65	1.13
S5	Pindi gheb	*Crocothemis erythraea, Rhodishnura nursei*	0.26	2.1	0.5	0	3.8	0.5	0.49	1.7
S6	Bhara Kahu	*Pseudagrion decorum*	0.32	2.5	0.7	0	2.7	0.8	0.63	0.2
S7	Mohra	*Crocothemis erythraea*	0.38	3	0.8	0	3.5	0.9	0.65	0.5
S8	Bobry	*Acisoma panorpoides panorpoides, Pseudagrion decorum*	0.31	2.6	0.5	0	3.2	0.6	0.43	0.6
S9	Shah Pur dam	*Crocothemis erythraea*	0.56	4.7	0.91	0	4.8	1.3	0.59	0.1
S10	Murree	*Pseudagrion decorum*	0.39	2.8	1.1	0	2.9	0.7	0.93	0.1
S11	Chakian	*Orthetrum chrysis*	0.41	3.3	0.8	0	3.8	0.8	0.62	0.5
S12	Narar	*Trithemis aurora*	0.62	3.5	0.7	0	5.7	1.2	0.42	0.2
S13	Kahuta	*Crocothemis servilia, Pseudagrion decorum*	0.75	6.2	1.31	0	6.3	1.4	0.74	0.1
S14	Rawal dam	*Libellula fulva, Trithemis kirby kirby, Trithemis pallidinervis, Ceriagrion pulchellum,*	0.43	3.9	0.4	0	4	0.8	0.28	0.1

S15	Pind Bhagwal	*Boyeria iriene*	0.47	1.6	3.1	0	3.2	1.2	3.48	1.6
S16	Athal Colony	*Crocothemis erythraea*	0.52	4.1	1.15	0	4.3	1.2	1.04	0.2
S17	Shadara	*Cordulegaster brevistigma, Neurothemis tullia tullia*	0.59	4.4	1.53	0	4.6	1.4	1.03	0.2
S18	Simly dam	*Orthetrum sabina*	0.83	3.6	4.75	0.12	4.62	2.95	3.54	1.14
S19	Ghabeer Nala	*Ceriagrion coromandelianum*	0.59	4.17	1.74	0	3.92	1.8	1.21	Nil
S20	Taja Bara	*Crocothemis erythraea*	2.38	5.32	18.48	0.64	16.54	4.92	11.34	11.86
S21	Fateh Jang	*Boyeria iriene*	0.35	3.15	0.4	0	2.94	0.52	0.32	Nil
S22	Jatla	*Crocothemis servilia*	1.42	5.35	8.86	0.6	7.42	5.6	5.4	2.67
S23	Kheri Moorat	*Crocothemis erythraea*	0.77	4.24	3.5	0	4.14	3	2.39	Nil
S24	Dhok Syedaan	*Sympetrum fonscolumbei*	2.16	7.62	13.98	2.2	12.44	5.4	7.17	7.02
S25	Bhurpur	*Selysiothemis nigra, Crocothemis erthraea*	1.06	2.97	7.67	1	4.6	4.32	6.28	2.63
S26	Thoha Mehram Khan	*Cordulegaster brevistigma, Orthetrum chrysostigma luzonicum*	0.8	2.78	5.26	0	4.82	3.1	4.45	2.04
S27	Kattas	*Crocothemis erythraea*	1.08	4.33	6.53	0.64	7.82	2.14	4.44	4.13
S28	Chua Saidan Shah	*Gomphidia t-nigrum*	2.05	13.94	6.56	0	9.56	8.24	2.48	Nil
S29	Chakwal	*Crocothemis erythraea*	2.08	8.77	12.03	2.2	13.24	3.95	5.76	6.67
S30	Tallian	*Enallagma parvum, Ishnura senegalensis*	1.56	3.71	11.96	1.2	7.88	4.75	8.79	5.37
S31	Nara Mator	*Boyeria irene*	0.61	4.27	1.92	0	4.82	1.22	1.32	0.55
S32	Dina	*Gomphidia t-nigrum*	0.74	6.52	0.94	0.82	4.22	2.5	0.52	Nil
S33	Kotli Sattian	*Anax immaculifrons*	0.77	2.84	4.91	0	3.62	2.82	4.12	1.6
S34	Mandra	*Anax immaculifrons*	0.54	3.96	1.52	1.4	3.3	1.8	1.07	Nil
S35	Qutball	*Crocothemis servilia, Crocothemis erythraea*	0.26	1.68	0.95	0	1.72	0.78	1.04	0.04

The results indicate that among 16 out of total 35 visited sites, Anisopterous genus *Crocothemis* (family Libellulidae) was dominant at sites having higher value for Sodium (NA), Bicarbonates (Bc), Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC). However, at sites having a higher concentration of Chloride and Calcium & Magnesium (Ca+Mg), Anisopterous genus *Gomphidia* (family Gomphidae) was prevalent. Genus *Sympetrum* (family Libellulidae) was seen at sites representing highest concentration of Carbonates. While members of genus *Orthetrum* (family Libellulidae) were found to second to *Crocothemis* at sites showing high concentrations of Bicarbonates (Bc). In case of damselflies (Zygoptera) Genus *Ischnura* of family Ceonagrionidae was observed to be adaptive with higher concentrations of Sodium (NA). While genus *Pseudagrion* (family Ceonagrionidae) showed a better tolerance towards Bicarbonates (Bc) followed by genus *Ceriagrion* of same family. It was founded that sites showing higher Ca+Mg concentration lacked any Anisopterous naiad, yet it was inhabited by Zygopterous larvae of genus *Ceriagrion* only.

For variations in levels of salinity at visited sites, it is evident from Figs 2-9 that highest values for Electrical Conductivity (Ec), Residual Sodium Carbonate (RSC), Sodium Absorption Ratio (SAR), Bicarbonates (Bc) and Sodium (Na) was observed at Taja Bara. While highest Calcium+Magnesium (Ca+Mg) ratio was recorded at Chakwal. Highest concentration for Chloride was observed at Chua Saidan Shah while Carbonates were higher at Dhoke Syedaan site. Information above is in accordance with the findings of Hannam (1998) who stated chemical composition of water affects species composition of Odonata with members of family Libellulidae as most dominant in and adaptive to low pH and alkaline waters.

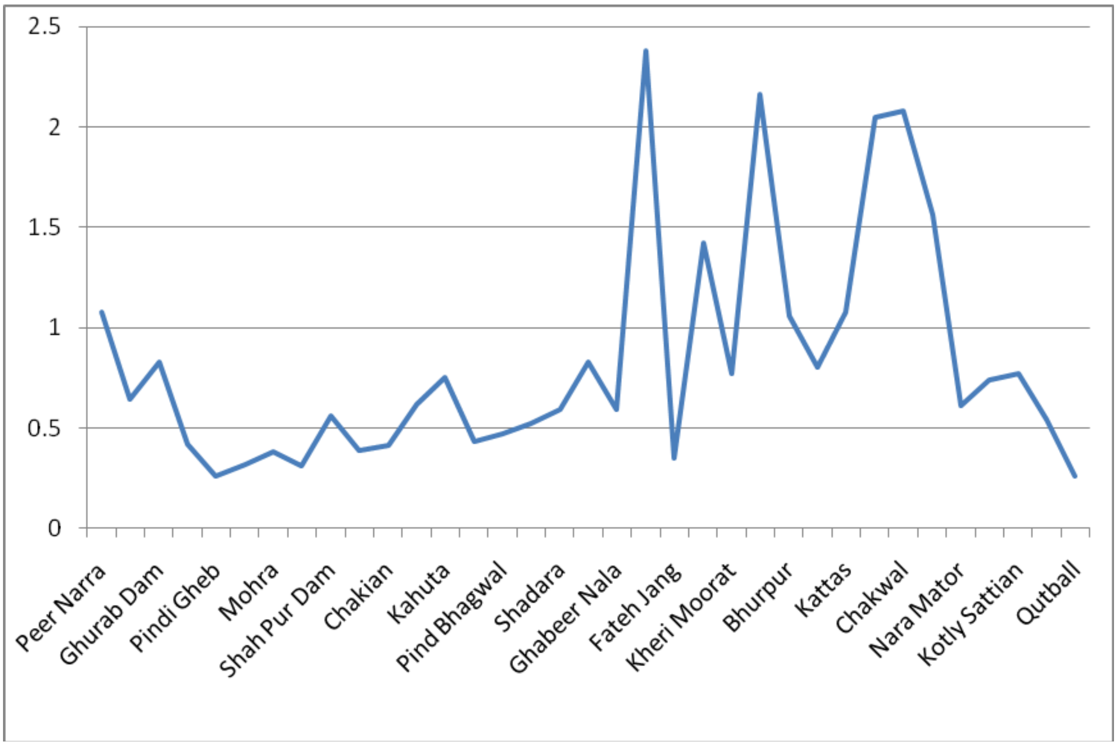

Fig. 2 Concentrations of Electrical Conductivity at surveyed sites.

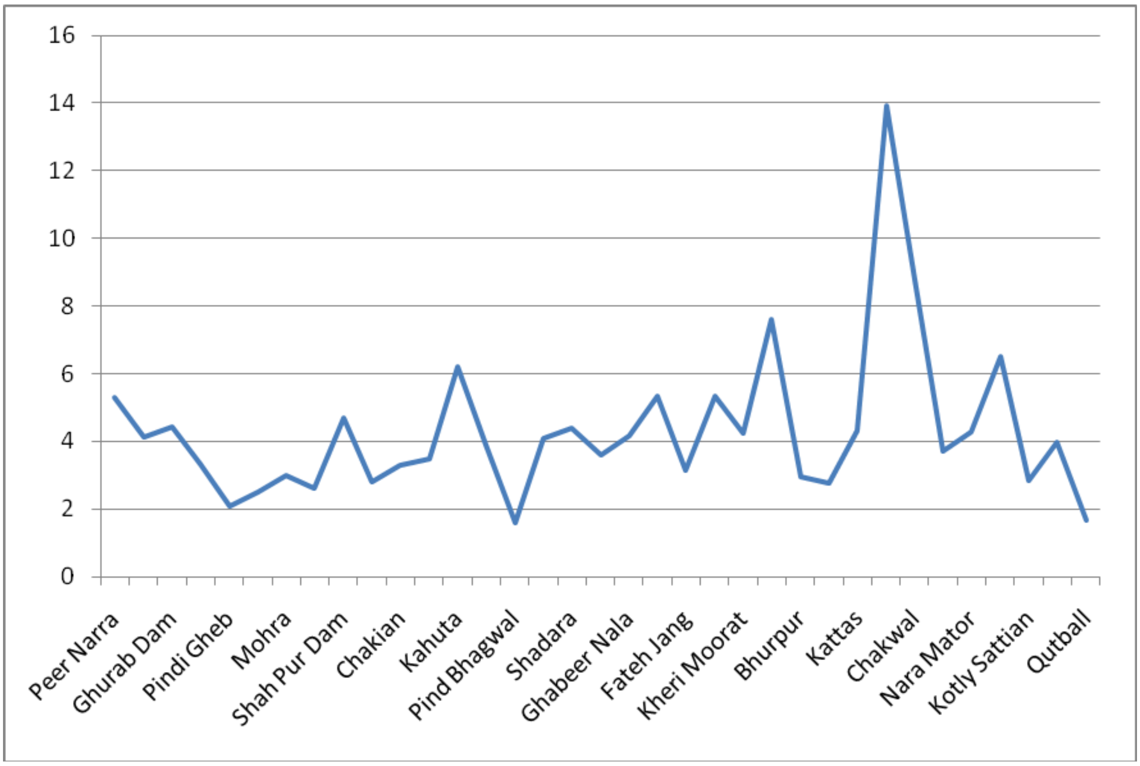

Fig. 3 Concentrations of Calcium + Magnesium (Ca+Mg) at surveyed sites.

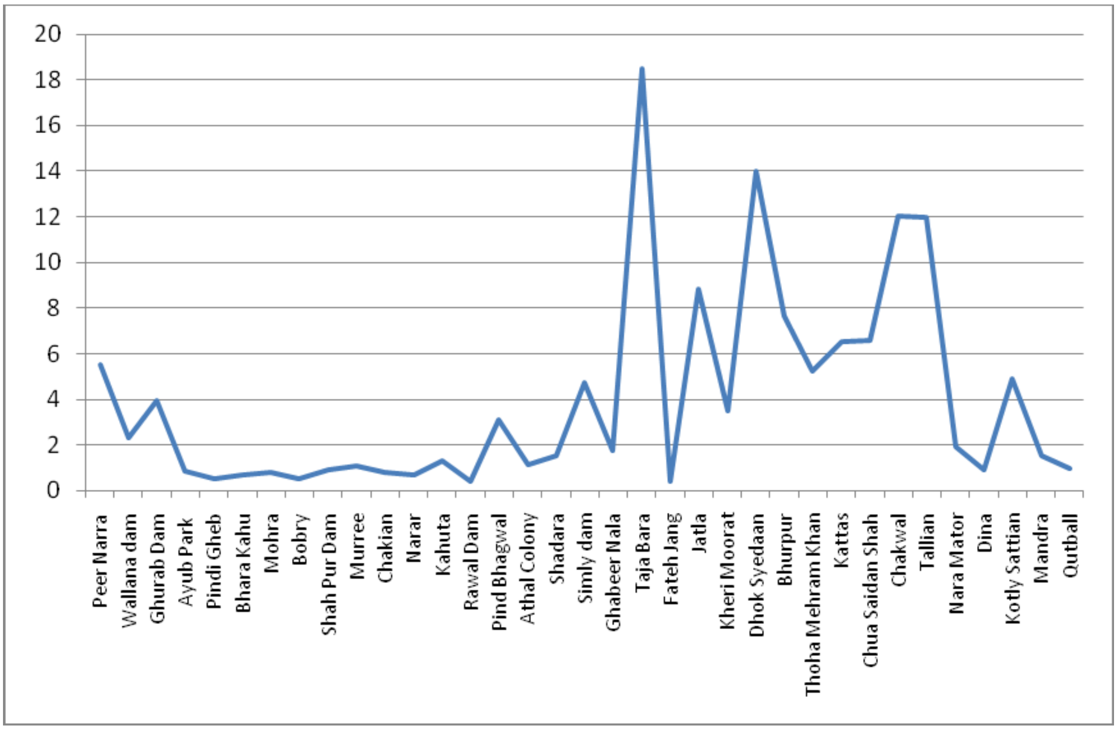

Fig. 4 Concentrations of Sodium (Na) at surveyed sites.

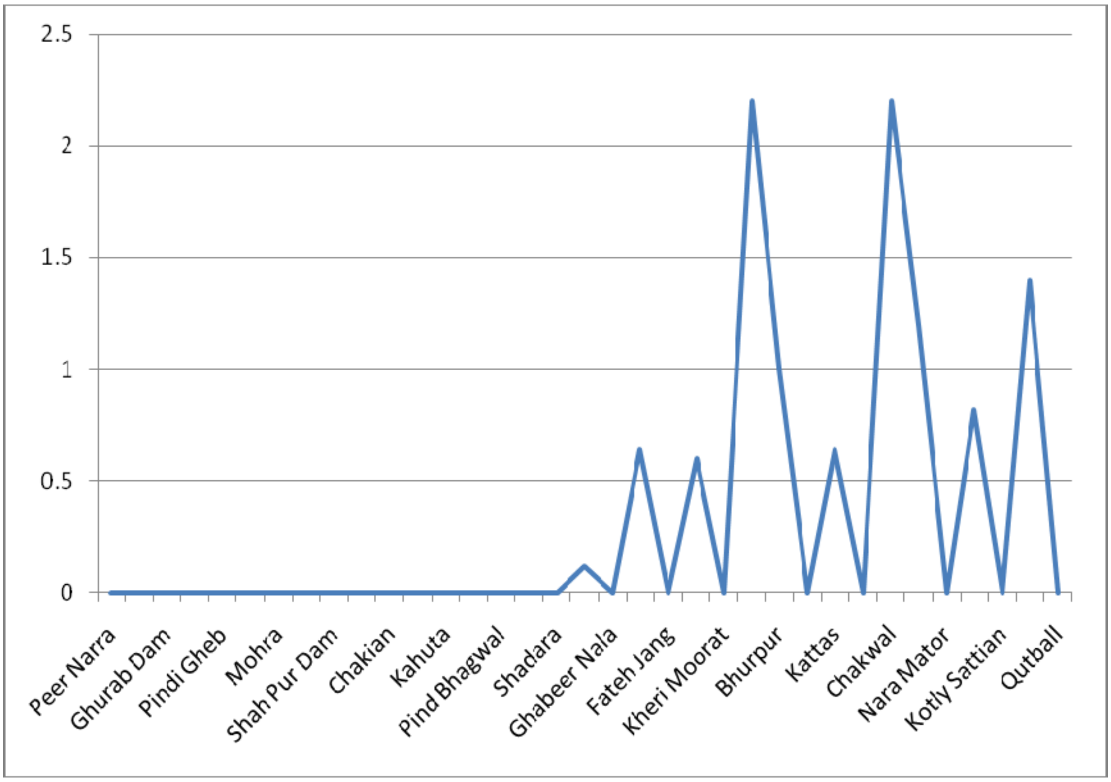

Fig. 5 Concentrations of Carbonates at surveyed sites.

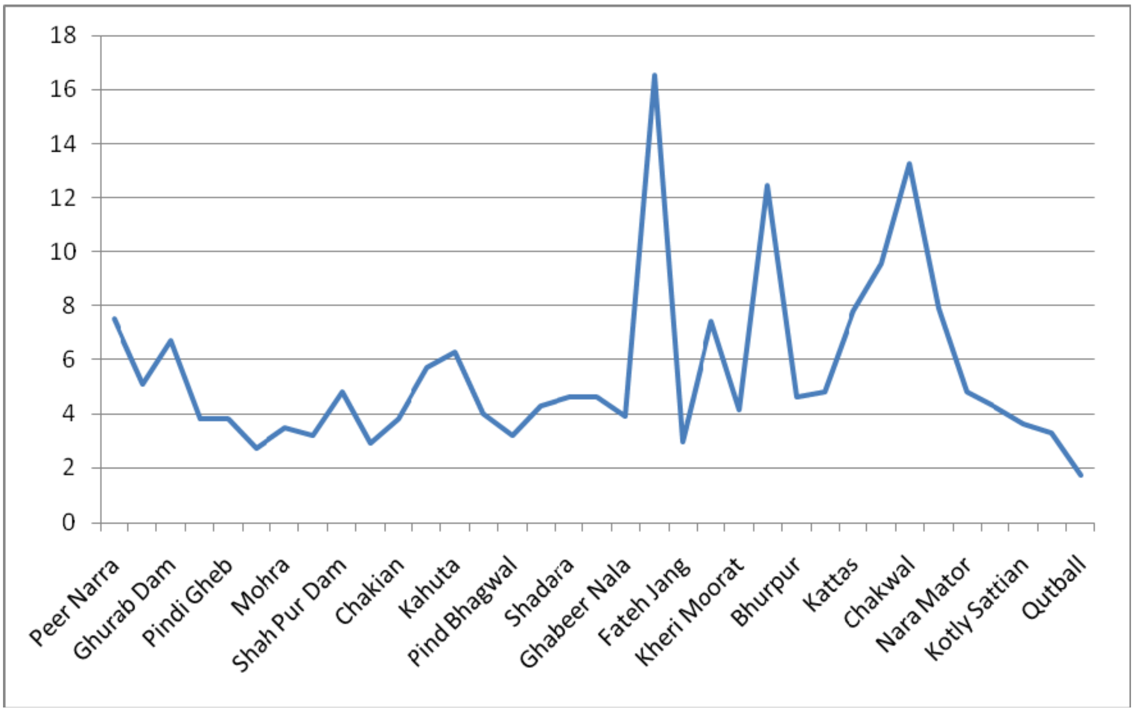

Fig. 6 Concentrations of bicarbonates at surveyed sites.

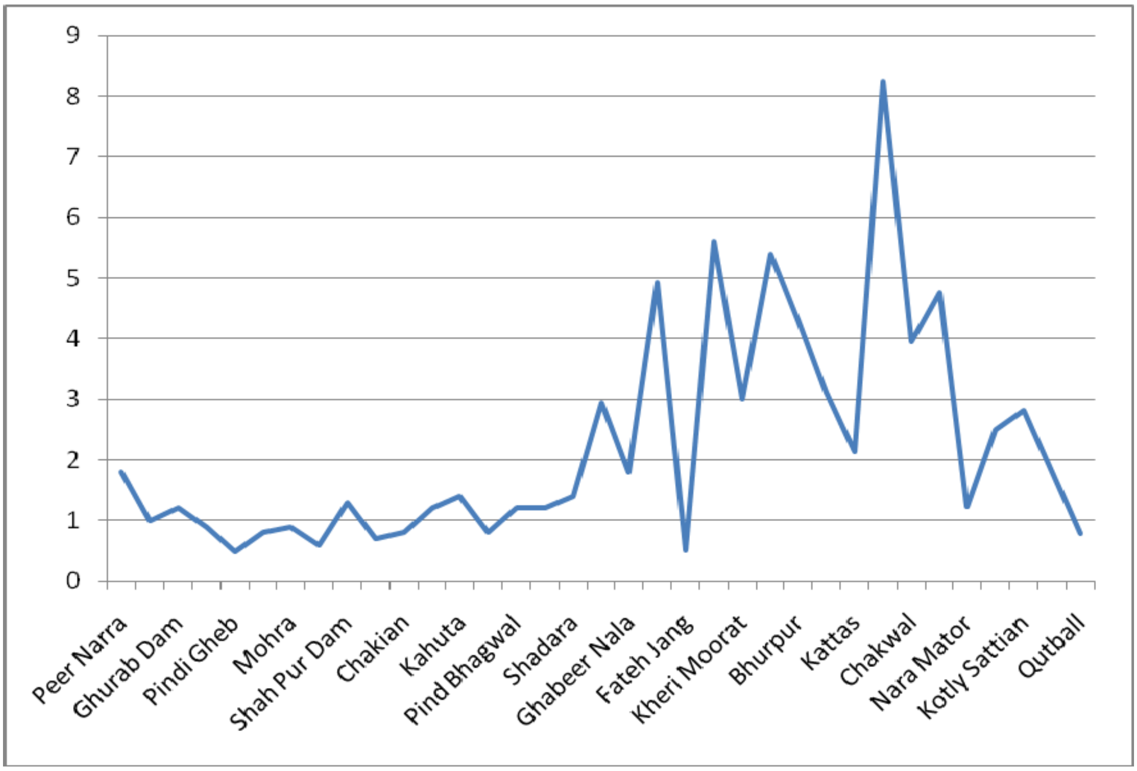

Fig. 7 Concentrations of Chlorides at surveyed sites.

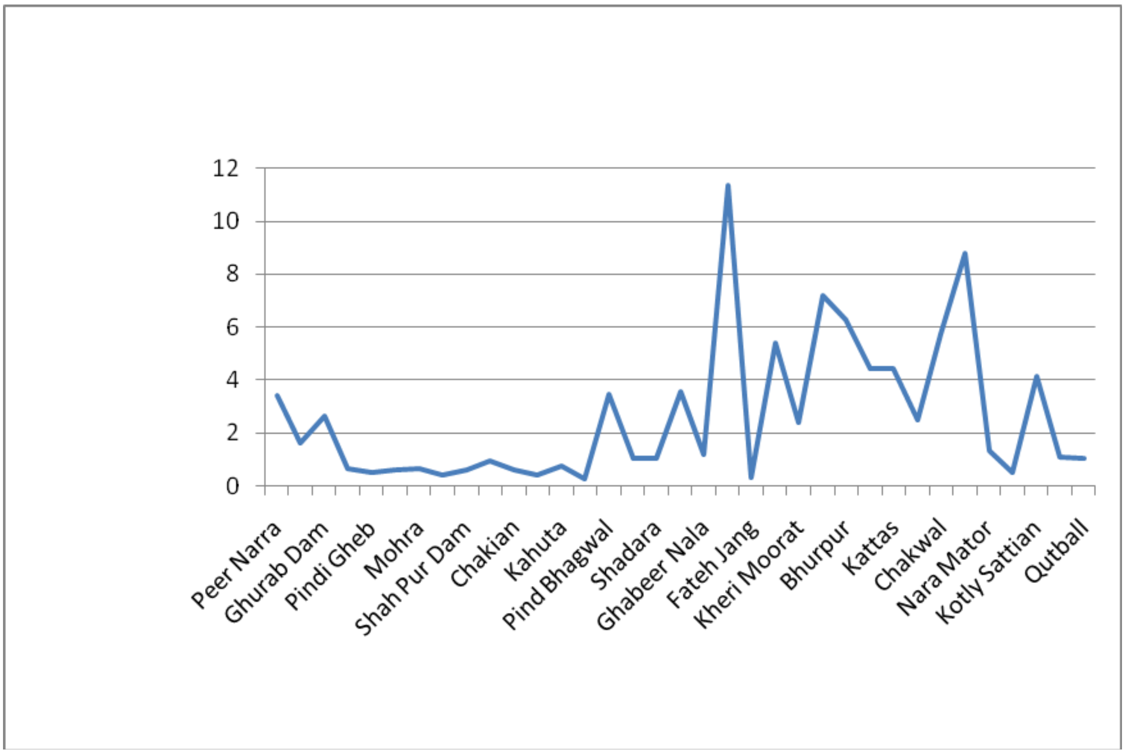

Fig. 8 Concentrations of SAR at surveyed sites.

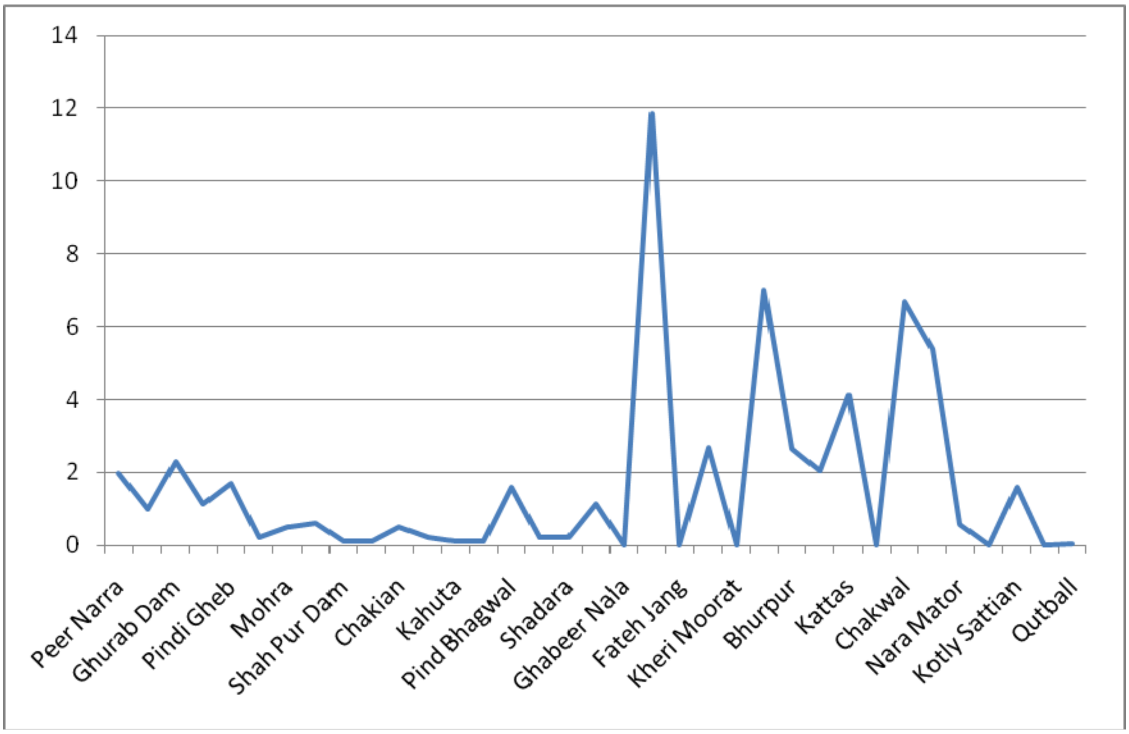

Fig. 9 Concentrations of RSC at surveyed sites.

Table 2 Descriptive statistics of all parameters determining salinity.

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Sampling Sites	1.00	35.00	18.0000	10.24695	.000	.398	-1.200	.778
EC	.26	2.38	.8294	.57501	1.508	.398	1.407	.778
Calcium	1.60	13.94	4.3174	2.27618	2.527	.398	8.872	.778
Sodium	.40	18.48	3.9460	4.44708	1.705	.398	2.609	.778
Carbonates	.00	2.20	.3091	.60879	2.121	.398	3.913	.778
Bicarbonates	1.72	16.54	5.5291	3.19913	1.936	.398	3.886	.778
Chloride	.50	8.24	2.2146	1.82299	1.544	.398	2.238	.778
SAR	.28	11.34	2.6089	2.69603	1.563	.398	2.259	.778
RSC	.00	11.86	1.6631	2.56580	2.478	.398	6.912	.778
Valid N (list wise)								

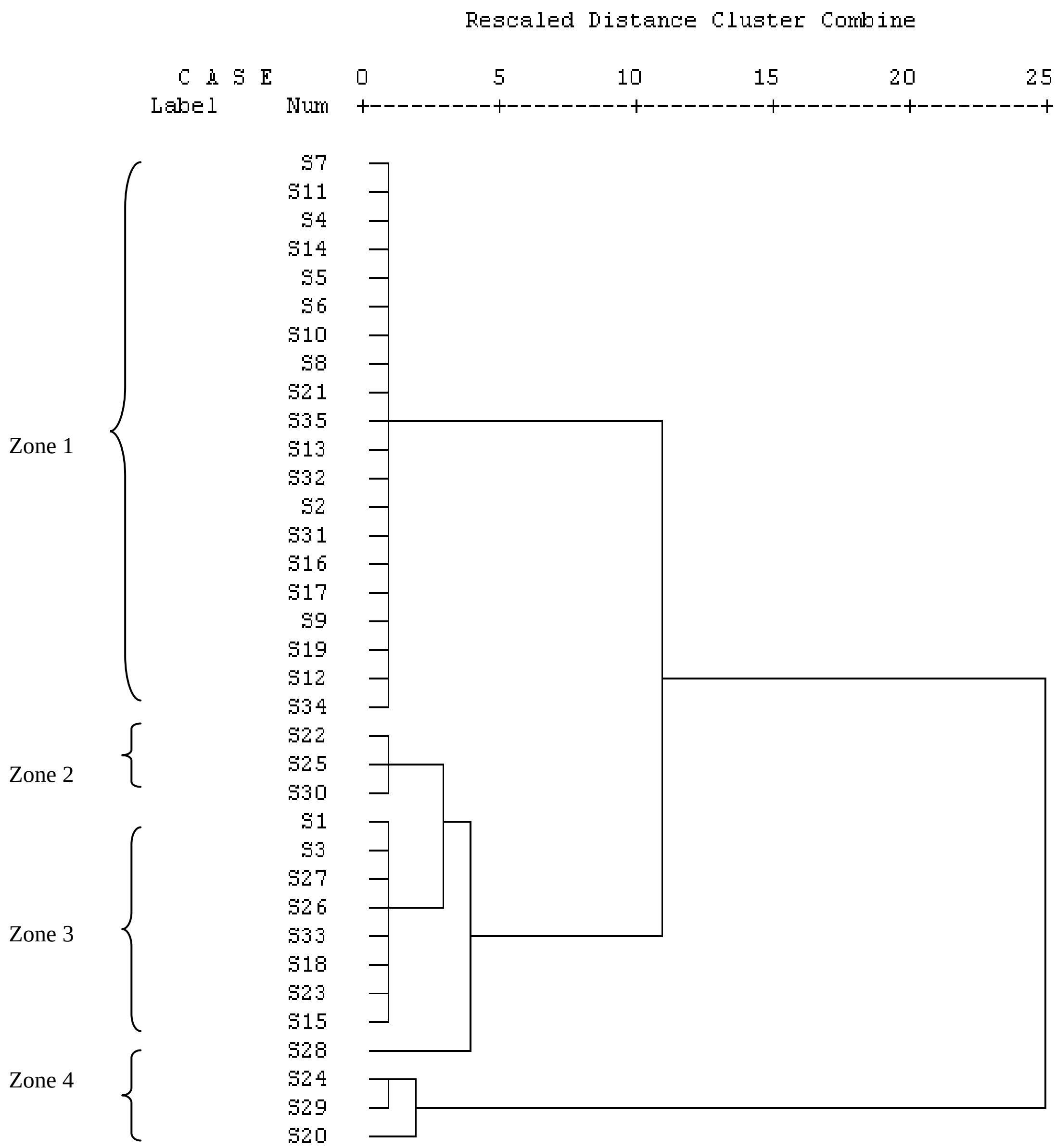

Fig. 10 Dendrogram of the cluster analysis using Ward's method applied for salinity.

Hierarchical Agglomerative Cluster Analysis (HACA) using Wards Method as a clustering technique was used for grouping of all surveyed sites using SPSS 16.0 (Statistical Package for Social Sciences). Dendrogram of cluster analysis applied for salinity (sodium, calcium, chloride, carbonate and bicarbonate ions) was drawn for all studied sites. Cluster analysis grouped visited sites into four different assemblages called zones in present study. All localities involved in one assemblage are significantly different from localities in other zones. Highest values were recorded for Zone 4 (S24, S29, and S20) with Zone 2 (S22, S25, S30) as the second highest in terms of salinity followed by Zone 3 and Zone 1 (Fig. 9).

Electrical Conductivity (EC) presented major values at S20, S24, S28, S29 and S30 (Zone 4 and 2) and lowest values were recorded from Zone 1. Total Calcium ions concentration varied from highest values at S24, S28 to lowest values at localities S11, S6, and S7. Similar trend were observed for Sodium and Chloride ions as it showed major values at S22, S30 while minor values were reported for S2 to S9. Both calcium and sodium ions contribute towards total electrical conductivity in aquatic ecosystem and thus affect insect species. Among Anisoptera, species of genus *Crocothemis* and *Gomphidia* were predominant in localities in Zone 4 and 2. Whereas carbonate ions showed very interesting trend and highest concentration for S18, S23, S26 (Zone 3). Localities in Zone 1 showed zero count for carbonates. Naiads under genus *Sympetrum* and *Orthetrum* showed higher abundance in this zone. Bicarbonate presented consistency with sodium, calcium and chloride ions and most of the species collected from these sampling sites included from genus *Orthetrum* (Anisoptera) and *Pseudagrion* (Zygoptera). In contrast to bicarbonates, Sodium Absorption Ratio (SAR) reaches to its peak at S20, S30 and S29 and is very similar to RSC (Figs 7 & 8).

Correlation analysis is a test of association of different variables and test of correlation analysis (Zhang and Li, 2015). Obtained results are displayed in Table 3. Inter-element relationship provided significant information on their sources and our results clearly depicted that strong correlation is present among all measured parameters determining salinity.

Table 3 Pearson correlation coefficient matrix for all parameters determining salinity.

	EC	Calcium	Sodium	Carbonates	Bicarbonates	Chloride	SAR	RSC
EC	1							
Calcium	.715**	1						
Sodium	.931**	.417*	1					
Carbonates	.657**	.371*	.666**	1				
Bicarbonates	.940**	.639**	.887**	.595**	1			
Chloride	.876**	.708**	.777**	.515**	.681**	1		
SAR	.827**	.223	.966**	.587**	.766**	.711**	1	
RSC	.800**	.224	.926**	.625**	.867**	.521**	.900**	1

It was observed that Electrical Conductivity (EC) and sodium and chloride ions showed significant positive correlation (r = 0.93) and both have strong positive association for determining salinity. Similarly, positive association was observed for sodium and carbonates (r = 0.67), sodium and bicarbonates (0.940), calcium and chloride (r = 0.87) and for RSC and SAR (r = 0.900). Overall positive significant correlation was recorded for all parameters which point out that all factors are equally affecting studied aquatic ecosystems.

Significant correlations between sodium, chloride and calcium presented their origin from single parent material and studies showed that their common natural parent source is organic matter. As indicated in present study, Zone 2 and Zone 4 includes localities showing highest concentration of theses ions, which is probably the effect of human anthropogenic activities as these localities were in close vicinity of urban areas. In a similar study, Azam et al. (2015) also pointed out aquatic ecosystems as a natural sink for all such ions that are spilled in water bodies through many factories and other anthropogenic activities, and pointed out their impacts on inhabiting insect fauna.

4 Discussion

The present work was conducted to test potential of Odonata naiads to be used in water quality diagnoses studies. The results were significant and clearly indicated Anisoptera naiads are more suitable than Zygoptera naiads while studying water salinity gradients. Importance and potential of Odonata naiads in assessing water quality standards were already discussed and stressed by various workers. Silsby (2001) discussed their importance as indicators of water quality in domestic water storage tanks. Similarly, Zia (2010) documented their use as water quality indicators and indicators of conditions of aquatic ecosystems. The present study was conducted in a plateau located at 32.50–34.00° N latitude, and 72–74° E longitude, covering an area of 23,161 km^2 at the junction of the Oriental region in the north of the Punjab and west of the Azad Jammu and Kashmir (Majeed, 2014) along the Himalaya’s foot hills. It presents a mixture of climate, ecology and water types. Here we present sweet water springs, brackish lakes, season streams, ponds and dams and rivers as well. So it was chosen as the sampling area for studying potential of Odonata naiads to withstand different levels of salinity gradients. Although few selected and simple factors were used in this study, but results obtained were important that obviously opened doors for future studies and similar trials. The study was first of its kind ever conducted. Although taxonomic work on Odonata adults remained a subject of interest in Pakistan since its birth (in 1947), yet naiads are very rarely studied with no research on their use or relation to water chemistry ever undertaken. Pakistan represents an Odonata fauna of over 120 species (Zia, 2016) and it is therefore suggested and stressed to work further on Odonata naiads in relation to water quality parameters.

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