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Association of Aquatic Invertebrates with the Water Quality in the Ponds of Bhaktapur

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Abstract

Aquatic invertebrates are representative of the health of habitats they live in. This study was conducted to evaluate aquatic invertebrate diversity and relate them with physico-chemical factors in the ponds of Bhaktapur. Rani pokhari, Bhajya pokhari, Na pokhari and Kamal pokhari were selected for the study. Plankton net was swiped out for approximately one minute in each corner of all the ponds. Five subsequent sweeps were taken repeatedly at each site. Invertebrates collected in the net were kept in a plastic container covered with a lid. The collected species were preserved in 70% alcohol. For physico-chemical analysis, water samples were collected from 10cm below the surface water in BOD bottles from each site and taken to the laboratory of Department of Zoology, Bhaktapur Multiple Campus for the further identification and laboratory work. Total 16 species of aquatic invertebrates belonging to five phyla, 10 orders and 16 families were recorded from the ponds of Bhaktapur. Species richness of aquatic invertebrates was found to be 13, 11, four and five in Rani pokhari, Bhajya pokhari, Na pokhari and Kamal pokhari respectively. Phylum Arthropoda was most abundant in all four ponds. The correlation of species richness with physico-chemical parameters showed a positive correlation with water temperature (r = 0.96), electric conductivity (r = 0.98), free carbondioxide (r = 0.99) and dissolved oxygen (r = 0.51) while the negative correlation with pH (r = -0.83) and alkalinity (r = -0.83). The result obtained is valuable and useful for continuous water quality monitoring activities and the conservation of freshwater fauna in the ponds of Bhaktapur. Further detailed studies on aquatic invertebrates were highly recommended.

Keywords: Plankton net, species richness, swiping method, water quality analysis

Introduction

Aquatic invertebrates are the diverse group of organisms including Protozoans to Echinoderms that live in the water. They also include species with terrestrial habitats spending some part of their life

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as aquatic organisms. They act as an integral part of the food chain. Without them, both the aquatic and terrestrial ecosystems may collapse. They play a significant role in the processing and cycling of nutrients including the biogeochemical cycle (Falkowski 1994) as they belong to many groups of predators, deposit collectors and filter feeders (Rosenberg & Resh 1993).

The aquatic environment covers 72% of the earth's surface but freshwater occupies only 0.8% supporting approximately 2% (Strayer 2010) of the estimated 6.7 million invertebrate species of the world (Böhm et al. 2012) compared to 16% (Mora et al. 2011, Appeltans et al. 2012) in extensive marine realm. The quality and quantity of water have impacts on the biotic communities of aquatic ecosystem. Alteration in these components results changes in the ecosystem diversity (Dallas 2000). The physico-chemical condition of an aquatic ecosystem regulates the community composition of aquatic invertebrates (Voshell 2002).

Despite having a significant role of aquatic invertebrates in nature, their studies are very limited. Most of the studies have focused only on the megafauna but the present study focused on feebly studied aquatic invertebrates and related their diversity with physico-chemical factors of their aquatic habitat. Study of aquatic invertebrates in Bhaktapur has not been conducted yet. To overcome this research gap, present study has been conducted which has provided very significant information to the local level government for the management of water quality and conservation of aquatic invertebrates.

Materials and methods

Among the 35 ponds of Bhaktapur, Rani pokhari, Bhajya pokhari, Na pokhari and Kamal pokhari were selected representing the ponds of Bhaktapur (Figure 1). Plankton net swiping method (Purkayastha & Gupta 2012) was applied to collect the species during the monsoon season from July to September. Plankton net with mesh size 1mm was swiped out for approximately one minute in each corner of the selected ponds. Five subsequent sweeps were taken repeatedly at each site. Invertebrates collected in the net were kept in a containers covered with lid and preserved in 70% alcohol (Borror et al. 1989). Microscopic invertebrates and water samples were collected in the Biological Oxygen Demand (BOD) bottles from 10 cm below the water surface. The samples were taken to the laboratory of Department of Zoology, Bhaktapur Multiple Campus for the further identification and laboratory works. Collected samples were observed in an Olympus compound microscope under 10X magnification. Species were identified on morphological basis by observing morphological features with the help of relevant keys (Imms et al. 1964), books (Bouchard 2004) and consultation with experts on the online platforms. Temperature and pH were recorded on the spot in the study sites using alcohol thermometer and pH meter respectively. Electrical conductivity (EC), Alkalinity, Free Carbondioxide (CO_2) and Dissolved Oxygen (DO) were examined on the same day in the laboratory by standard volumetric titration and instrumentation method as per APHA (2005). The association between the diversity of aquatic invertebrates and physico-chemical factors was determined using Simple Linear Regression Analysis and Karl Pearson's Correlation in RStudio 4.2.1-2022.

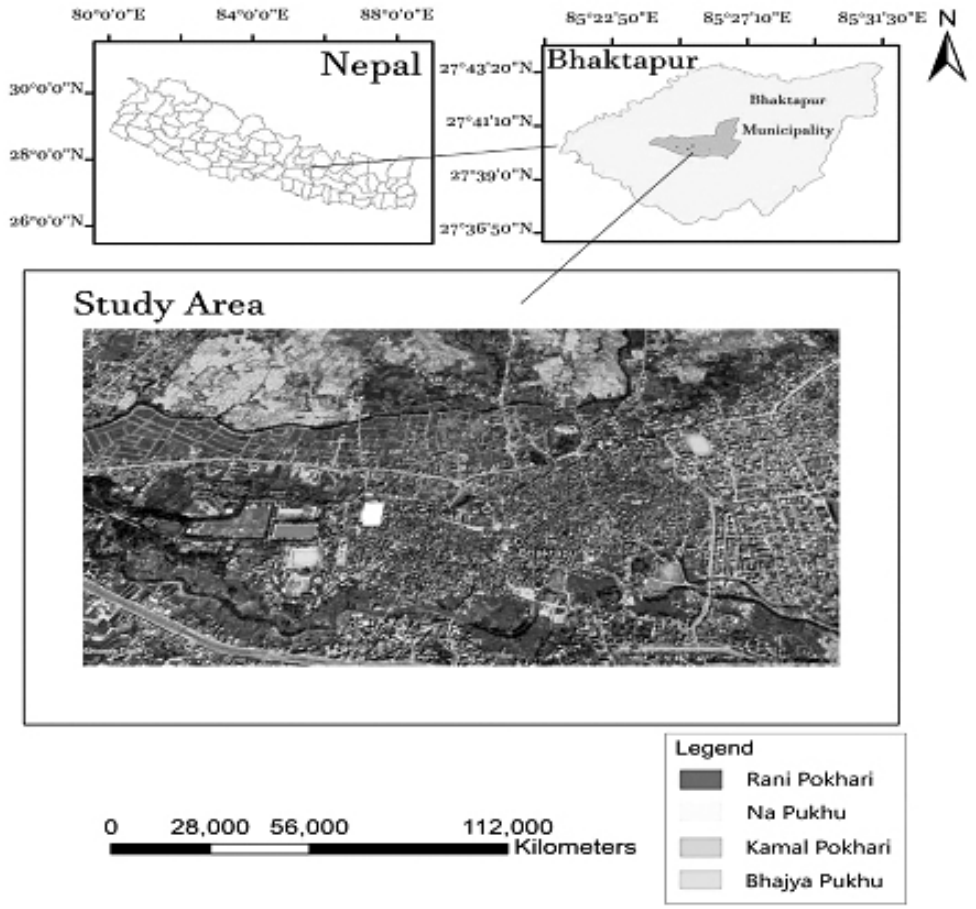

Figure 1. Map showing study sites

Results

Total 16 species (Figure 2 and 3) of aquatic invertebrates (Slipper animalcule, Nematode, Fresh water flatworm, Sludge worm, Dragonfly, Damselfly, Water boatman, Water scorpion, Common back swimmer, Common water strider, Midge, Cranefly, Dipteran larva, Copepod, Water flea and Freshwater snail) belonging to five phyla (Protozoa, Platyhelminthes, Annelida, Arthropoda and Mollusca), 10 orders (Peniculida, Rhabditophora, Tricladida, Oligochaeta, Odonata, Hemiptera, Diptera, Cyclopida, Cladocera and Gastropoda), 15 families (Parameciidae, Dalyelliidae, Planariidae, Naididae, Petaluridae, Coenagrionide, Corixidae, Nepidae, Notonectidae, Gerridae, Chironomidae, Tipulidae, Cyclopidae, Daphniidae, Lymnidae and) with one unidentified Dipteran larva were recorded from the ponds of Bhaktapur. Species richness of aquatic invertebrates was recorded 13, 11, four and five in Rani pokhari, Bhajya pokhari, Napokhari and Kamal pokhari respectively. Phylum Arthropoda was found to be the most abundant in all four ponds (Table 1).

Table 1. Aquatic invertebrates of ponds of Bhaktapur

Phylum	Order	Family	Species	Common Name	Rani pokhari	Bhajya pokhari	Na pokhari	Kamal pokhari
Protozoa	Peniculida	Parameciidae	*Paramecium* sp.	Slipper animalcule	+	+	+	+
Platyhelminthes	Rhabditophora	Dalyelliidae	*Castrella* sp.	Flatworm	+	-		
	Tricladida	Planariidae	*Planaria* sp.	Flatworm	+	-		
Annelida	Oligochaeta	Naididae	*Tubifex* sp.	Sludge worm	-	+		
Athropoda	Odonata	Petaluridae	*Anisoptera* sp. (nymph)	Dragonfly	+	+		
		Coenagrionide	*Zygoptera* sp. (nymph)	Damselfly	+	-		+
	Hemiptera	Corixidae	*Corixa* sp.(adult)	Water boatman	+	+	+	+
		Nepidae	*Ranatara* sp. (adult)	Water scorpion	-	+		
		Notonectidae	*Notonecta* sp. (adult)	Common backswimmer	+	+	+	
		Gerridae	*Gerris* sp.(adult)	Common water strider	+	+		
	Diptera	Chironomidae	*Chironomus* sp. (larva)	Midge	+	+	+	
		Tipulidae	*Tipula* sp. (larva)	Crane fly	+	-		+
		Unknown	Unknown sp. (larva)	Dipteran larva	-	+		
	Cyclopida	Cyclopidae	*Cyclops* sp.	Copepod	+	-		
	Cladocera	Daphniidae	*Daphnia* sp.	Water flea	+	+		+
Mollusca	Gastropoda	Lymnidae	*Lymnea* sp. (juvenile andadult)	Freshwater snail	+	+		
Total	**10**	**15**	**16**	**16**	**13**	**11**	**4**	**5**

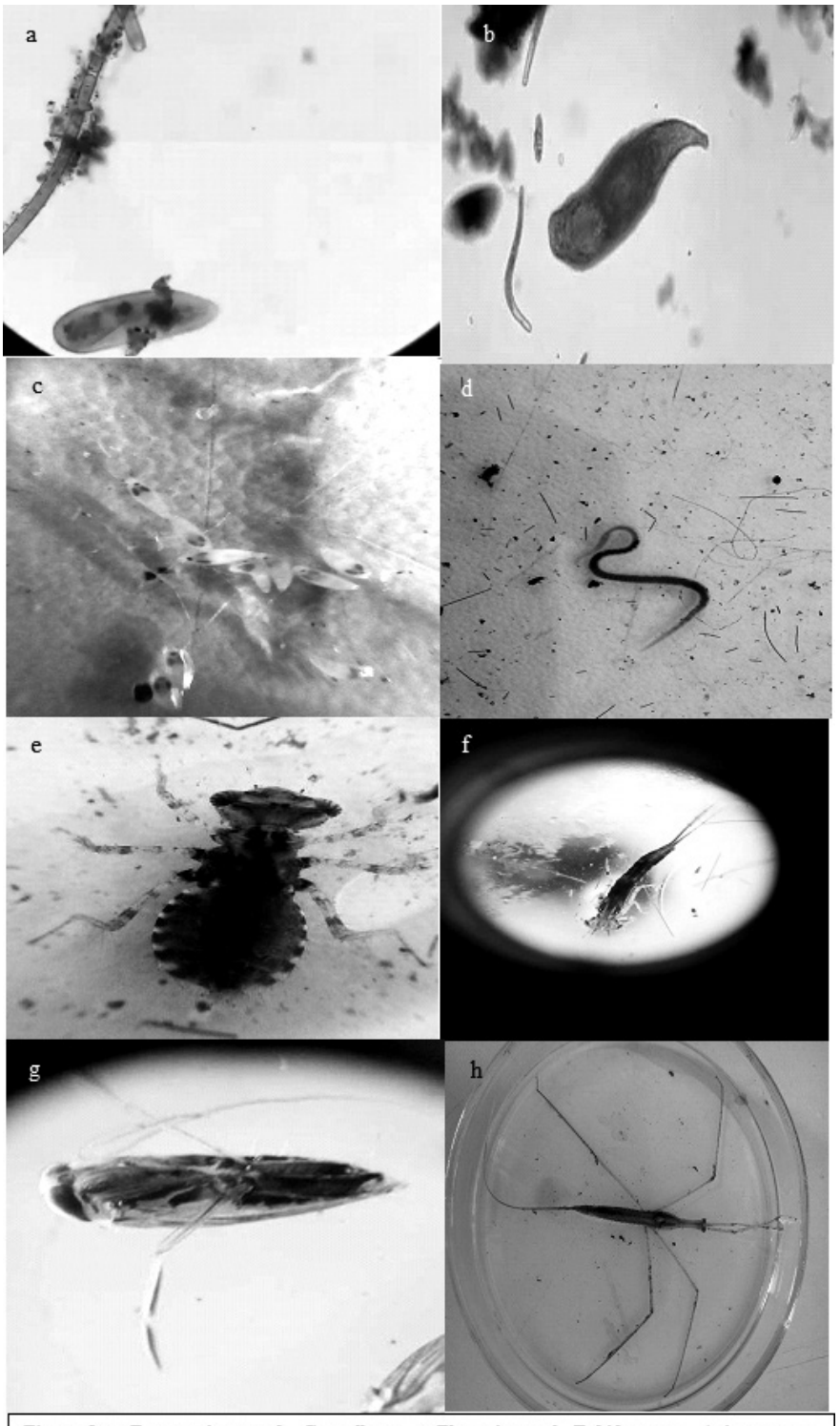

Figure 2. a. ***Paramecium sp.*****, b.** ***Castrella sp.*****, c.** ***Planaria sp.*****, d.** ***Tubifex sp.*****, e.** ***Anisoptera sp. (nymph)*****, f.** ***Zygoptera sp. (nymph)*****, g.** ***Coriaxa sp.*** **(adult), h.** ***Ranatara sp.*** **(adult)**

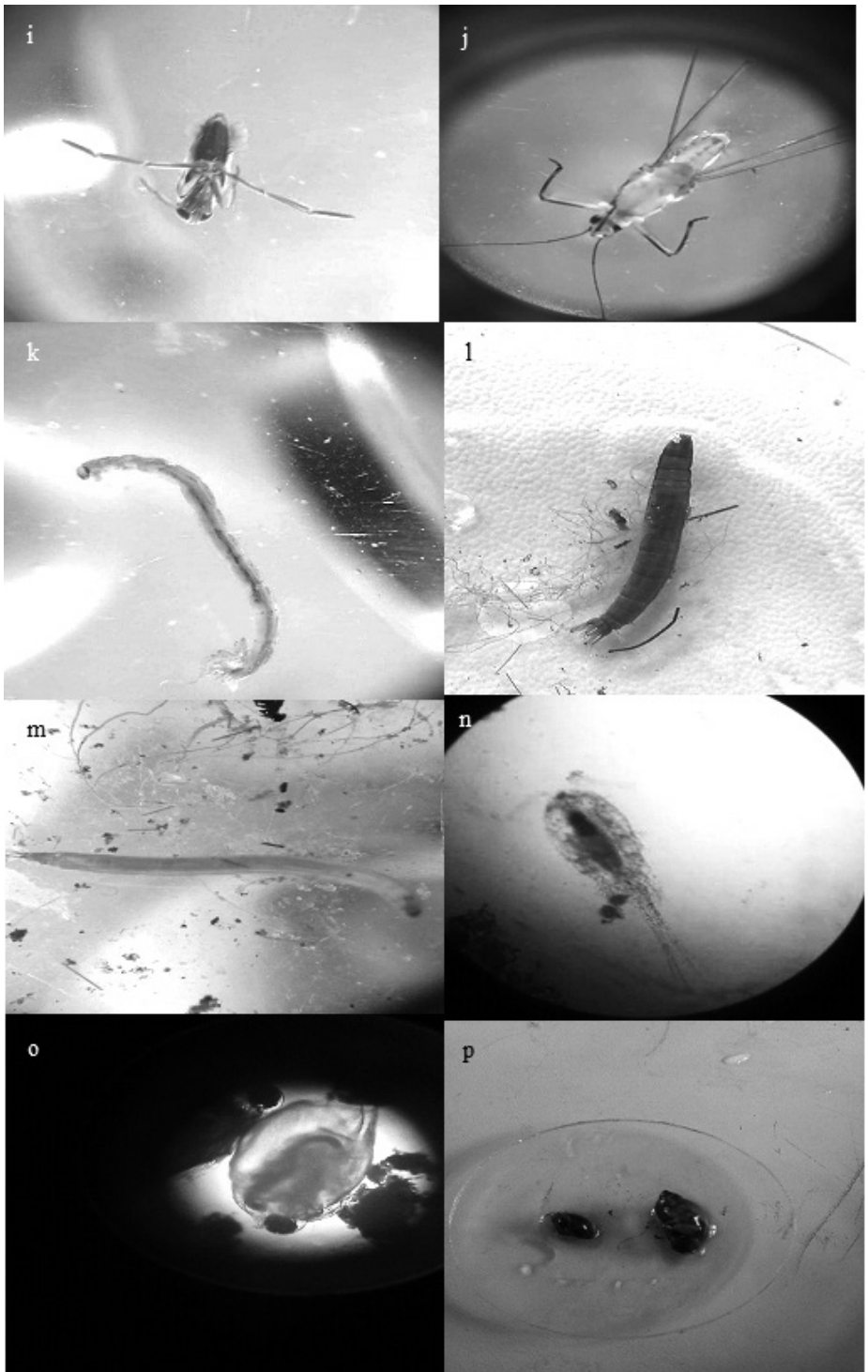

Figure 3. i. *Notonecta* sp. (adult), j. *Gerris* sp. (adult) k. *Chironomus* sp. (larva), l. *Tipula* sp. (larva), m. Unknown sp. (larva), n. *Cyclops* sp., o. *Daphnia* sp., p. *Lymnea sp.* (juvenile and adult)

Average water temperature recorded was 27◦C, 26◦C, 22◦C and 24◦C in Rani pokhari, Bhajya pokhari, Na pokhari and Kamal pokhari respectively. Similarly, pH measured was 8.25, 8.75, 10.5 and 9, EC was 231 µS/cm, 195µS/cm, 108 µS/cm and 92.75 µS/cm, Alkalinity was 23.37 mg/lt, 30.70 mg/lt, 32.97 mg/lt and 55.17 mg/lt, free CO_2 was 4.5 mg/lt, 4mg/lt, 2.5 mg/lt, and 3 mg/lt, DO was 21.2 mg/lt, 7.2 mg/lt, 10.8 mg/lt and 10.4 mg/lt in Rani pokhari, Bhajya pokhari, Na pokhari and Kamal pokhari respectively (Table 2). Species richness of aquatic invertebrates in the ponds of Bhaktapur was negatively correlated with pH (r= -0.83) and alkalinity (r= -0.68) whereas, positively correlated with water temperature (r= 0.95), EC (r= 0.98), free CO_2 (r= 0.99) and DO (r= 0.51) (Figure 4).

Table 2. Water quality of ponds of Bhaktapur

Physico-chemicalfactors	Acceptable limits (APHA2005)	Rani pokhari	Bhajya pokhari	Na pokhari	Kamal pokhari
Temperature (°C)	_	27	26	22	24
pH	7.0- 9.0	8.25	8.75	10.5	9
Electrical Conductivity (µS/cm)		231	195	108	92.75
Alkalinity (mg/lt)	50 - 150	23.37	30.70.	32.97	55.17
Free carbondioxide (mg/lt)	-	4.5	4		3
Dissolved oxygen (mg/lt)	12.0 - 25.0	21.2	7.2	10.8	10.4

The association of species richness of aquatic invertebrates was significant with water temperature (t=4.83, P=0.04), EC (t=7.39, P=0.02) and free CO_2 (t=10, 0.01) but there was insignificant association of species richness with pH (t= -2.1, P=0.17), alkalinity (t= -1.3, P=0.32), and DO (t=0.83, P=0.49).

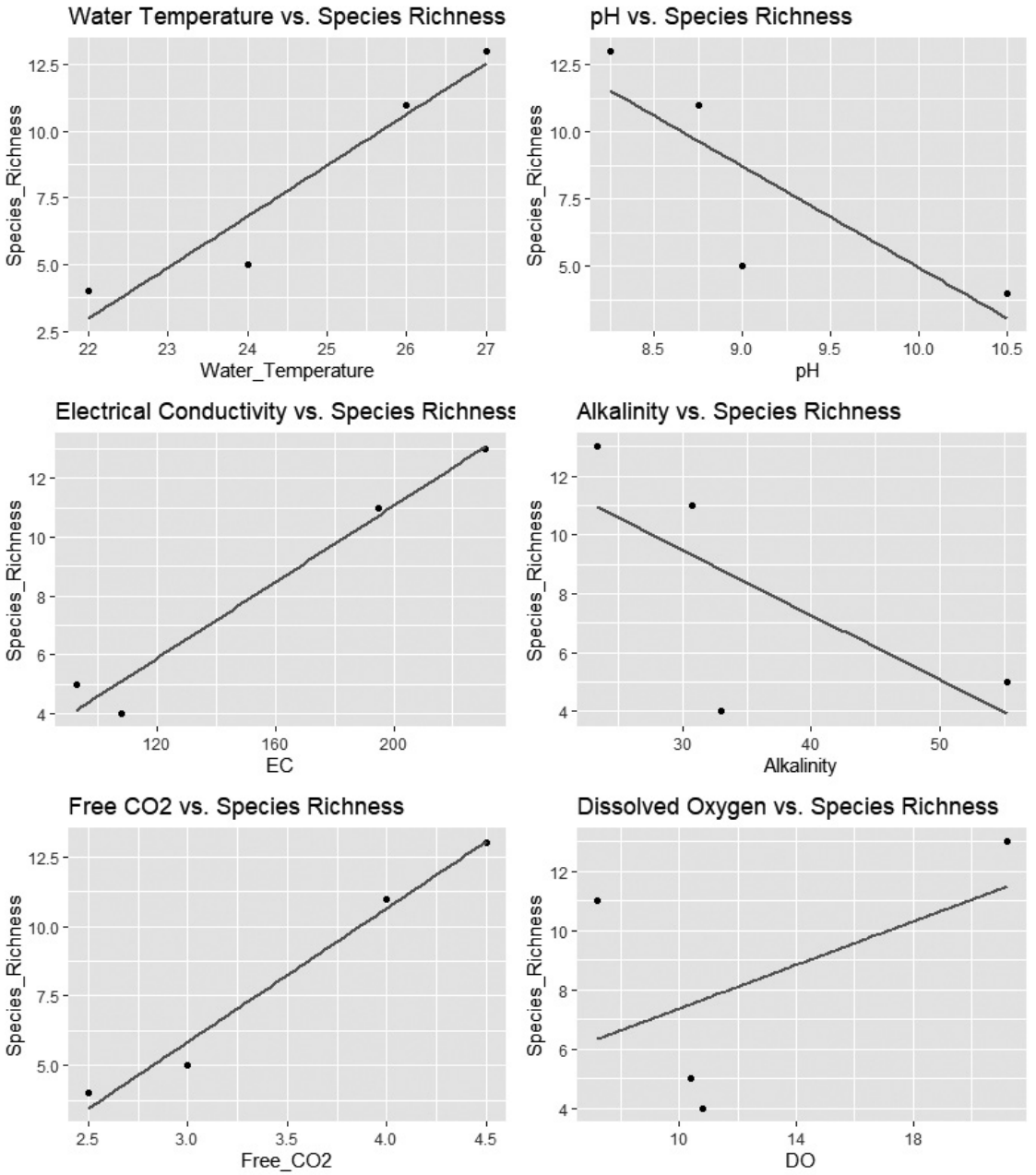

Figure 4. Scatter plots depicting the relationships between physico-chemical variables and species richness of aquatic invertebrates of ponds of Bhaktapur.

Discussion

In the present study, 16 species of aquatic invertebrates belonging to five phyla, ten orders and 15 families were recorded which was relevant with Mehta & Rana (2017) that recorded 27

taxa belonging to five invertebrate groups in Bagmati river; Niroula et al. (2011) listed 38 species of aquatic macro-fauna in Betana pond, Eastern Nepal and Shah et al. (2011) recorded 50 taxa of littoral benthic invertebrates belonging to 15 orders in Jagdishpur reservoir. Present study recorded higher species of aquatic invertebrates than thatof Dhakal (2006) which recorded only 10 taxa of aquatic invertebrates belonging to four phyla in Balkhu Khola. Since the studies were conducted in different geographic locations, the difference might be attributed to distinct environmental factors or the community composition of the study areas (Beisel et al. 2000).

Higher species richness of Phylum Arthropoda in all four ponds was relevant with that of Mehta & Rana (2017) which also recorded Phylum Arthropoda as the most abundant phylum in Bagmati river. In this study, among Arthropoda, order Hemiptera was found to be more dominant in all four ponds. Similar findings were observed by Agarwala et al. (2013), Prakash & Verma (2020), Ganie et al. (2022) and Mendoza & Mendoza (2022). The dominance of phylum arthropods and order Hemiptera might be because of their ability to exhibit diverse strategies for adaptation (Li et al. 2017).

In the present study, species richness of aquatic invertebrates was higher (13 species) in undisturbed and vegetation rich Rani pokhari; whereas, lower (four species) in disturbed and poor vegetation containing Na pokhari. This result concurred with that of Agarwala et al. (2013) who recorded higher species richness (31 species) in Maharaja Bir Bikram College lake with rich vegetation and lower species richness (11 species) in Laxminarayan Bari lake with poor vegetation in India. Shrestha (1992) found higher species diversity in less polluted sites than the polluted sites in Bagmati river, which is similar with the present study in which high species richness was found in Rani pokhari (less polluted) whereas, low species richness was recorded in Na pokhari (polluted with human interferences). This is also in line with Andem et al. (2012), who suggested that species richness is degraded due to environmental stress caused by higher anthropogenic activities.

Water temperature is an important physical parameter influencing the chemistry and biological reactions in the organism in water (Trivedy & Goel 1984). The maximum temperature (27°C) was recorded in Rani pokhari and minimum temperature (22°C) was recorded in Na pokhari. The water temperature is affected by many factors such as time period, exposure to the radiation and climate (Welch 1952). In the current study, species richness showed significant relationship ($P = 0.04$) and positive correlation ($r = 0.96$) with temperature. Similar findings were noted by Nasiruddin et al. (2019) and Mendoza & Mendoza (2022).

pH of water affects the productivity of the water system. The acceptable range of pH for largest varieties of freshwater aquatic organisms is 6.5 to 9.0 (EPA 1986). The pH values in Rani pokhari, Bhajya pokhari and Kamal pokhari are within the acceptable range. Similar observation was noted by Matangulu et al. (2017) in Seti river of Bajhang. On the contrary, the current result recorded pH of Na pokhari which was higher than the acceptable range. The increase in pH might be due to release of detergent from washing clothes and vehicles. Sharma (2004) and Mendoza & Mendoza (2022) revealed a positive correlation between the invertebrate diversity and pH of water. However, in the current study, species richness showed no significant relationship ($P=0.38$)

hence, negative association (r= -0.83) with pH of water which was relevant with that of Berezina (2001). In this study, pH of Rani pokhari (8.3) and Bhajya pokhari (8.8) was recorded as slightly alkaline, whereas, that of Na pokhari (10.5) and Kamal pokhari (9) was recorded as highly alkaline. Some evidence in this study tends to support the expected influence of pH on species richness. Rani pokhari showed a higher species richness in line with its acceptable pH. Conversely, Na pokhari with pH higher than acceptable range exhibited lower species richness. However, with the statistical analysis suggesting no significant relationship, the change in species richness cannot be completely contributed to pH of the water.

Electrical conductivity is the conduction of electrical current through the substance. Electrical conductivity within the range 150- 500µS/cm is considered suitable for aquatic habitat (APHA 2005). The present study showed higher value (231 µS/cm) of electrical conductivity in Rani pokhari and lower (92.75 µS/cm) in Kamal pokhari which is within the optimum range. The current study observed significant relation (P=0.02) and positive correlation (r=0.98) between species richness and electrical conductivity, which is in line with Laurince et al. (2019) which is not in agreement with Nasiruddin et al. (2019) and Prommi & Payakka (2015). Higher EC leading to higher species richness of aquatic invertebrates might be because of the increased productivity. The dissolved ions provide essential nutrients for plants and primary producers, which in turn supports diverse invertebrates, leading to high species richness (Wetzel 2001).

Alkalinity is the ability of water to neutralize acid. The current study recorded higher value (55.17 mg/lt) of alkalinity in Na pokhari and lower in Rani pokhari (30.70 mg/lt). Despite the variation, both values are within the range of optimum value of alkalinity (50-150 mg/lt) in which aquatic invertebrates can survive (APHA 2005). Statistical analysis revealed no significant relationship (P=0.32) and negative correlation (r= -0.83) between species richness and alkalinity. Contrasting results were found by Abhilash & Mahadevaswamy (2021), as insect diversity seemed to be dependent on the alkalinity of water. Our results contradict the general expectation that higher alkalinity levels would increase the species richness (Vestergaard & San-Jensen 2000). This might be because of interplay of other physico-chemical parameters as well as influence of anthropogenic disturbances (Andem et al. 2012).

Free Carbon dioxide is a vital constituent for the aquatic environment (Welch 1952). The optimum value of free CO_2 necessary for aquatic habitat is 12.0 to 25.0mg/lt (APHA 2005). In present study, maximum value (4.5mg/lt) of free CO_2 was observed in Rani Pokhari and the minimum (2.5 mg/lt) in Na Pokhari. The low value of free CO_2 in Na pokhari might be attributed to basic pH of water. Similarly, the current study showed a significant association (P=0.01) and strong positive correlation (r=0.99) between species richness and free CO_2 which is in favor with Dhakal (2006). The reason behind increase species richness with higher CO_2 levels can be attributed to the boost in primary productivity throughout the food webs as suggested by Goldenberg et al. (2017). However, the result was in contrast with Singhal et al. (1986) and Nasiruddin et al. (2019). The contrasting results might be because of difference in species composition and environmental factors geographically.

Sufficient amount of oxygen is required for aquatic invertebrates for driving their metabolism. George (1961) has mentioned sufficient amount of concentration of DO is required to maintain life in water. In the present study, the higher DO (21.2 mg/lt) was recorded in Rani Pokhari and lower (7.2 mg/lt) in Bhajya pokhari. Species richness showed positive correlation (r=0.51) with DO which is in agreement with Nasiruddin et al. (2019) and Mendoza & Mendoza (2022). However, the association was not significant (P=0.49). It has been observed that lower level of DO results in lethal effects in aquatic invertebrates (Connolly et al. 2004), signifying the importance of DO levels for aquatic invertebrates.

Conclusions

Present study has provided valuable information on the diversity of aquatic invertebrates and the quality of pond water of Bhaktapur. Total 16 species of aquatic invertebrates were found from the ponds of Bhaktapur. Species richness of arthropods was higher than other invertebrates. Hemipteran was the most diverse order in the ponds. Invertebrates from family Parameciidae and Corixidae were found in all the ponds. Non- disturbed Rani Pokhari has higher species richness of aquatic invertebrates than the disturbed and anthropogenically polluted Na Pokhari. Majority of aquatic invertebrates are surviving in alkaline aquatic environment with higher electrical conductivity, free CO_2, and DO upto certain limit. The water quality of ponds of Bhaktapur is within the acceptable limits for the survival of aquatic invertebrates and other organisms. These results obtained are valuable and useful for continuous water quality monitoring activities and conservation of freshwater fauna in the ponds of Bhaktapur. Further regular studies on aquatic diversity and other water parameters are highly recommended to establish pond water management and their conservation strategies in Bhaktapur.

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Authors' contributions

R.K., D.K.K. and N.D. conceptualized the study. R.K. conducted the field and laboratory works. R.K. and D.K.K. performed data analysis and prepared the draft of the paper. All authors read, gave their inputs and approved the final manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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