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Species diversity, abundance, and distribution of freshwater prawns along a selected perennial stream in Ngangla Gewog, Zhemgang, Southern Bhutan

by

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Abstract

The study and diversity of freshwater prawns are of great importance due to growing interest in biodiversity and its relative abundance. The present study was carried out for a selected stream divided into three different habitat types: namely, pond, run, and riffle. The study was focused on the diversity and abundance of prawns. To make it more systematic, a transect was laid upon the stream and it was divided into 30 plots with 100 m intervals. *Metapenaeus rosenbergii*, *Penaeus japonicas*, and *Metapenaeus insolitus* were species recorded in the pond habitat type only. The *Penaeus* genus was the most prominent in the study area while the genus *Metapenaues* was the least abundant. The diversity of freshwater prawns was found to be highest in the pond rather than the run and riffle. Documented information for prawn populations in Bhutan is sparse. Therefore, there is a wide research gap regarding prawn diversity in Bhutan. This study will help to establish a baseline data for the prawn distribution in the proposed study area. The present study will serve as a reference guide for future researchers.

Key words: Prawn farming, fresh water prawns, *Metapenaeus insolitus*, *M. rosenbergii*, *P. japonicas*, beta diversity, conservation

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1. Introduction

There are about 4048 known species of shrimps and prawns worldwide (Chan, 1998)corals, bivalves, gastropods, cephalopods, sto- matopods, shrimps, lobsters, crabs, holothurians, sharks, batoid fishes, chimaeras, bony fishes, estuarine crocodiles, sea turtles, sea snakes, and marine mammals. The introductory chapter outlines the environmental, ecological, and biogeographical factors influencing the marine biota, and the basic components of the fisheries in the Western Central Pacific. Within the field guide, the sections on the resource groups are arranged phylogenetically according to higher taxonomic levels such as class, order, and family. Each resource group is introduced by general remarks on the group, an illustrated section on technical terms and measurements, and a key or guide to orders or families. Each family generally has an account summarizing family diagnostic characters, bio- logical and fisheries information, notes on similar families occurring in the area, a key to species, a checklist of species, and a short list of relevant literature. Families that are less important to fisheries include an abbreviated family account and no detailed species information. Species in the important families are treated in detail (arranged alphabetically by genus and species. Freshwater prawns are found in rivers, streams, canals, and ponds in both hills and plains (Ahsan et al., 2014; Montgomery, 2010). Freshwater species, especially prawns and shrimps are increasingly popular in the aquarium trade and commercial industries due to their rich protein content.

'Prawn' and 'shrimp' are used interchangeably as neither refers directly to any of the known taxonomic groups (Chan 1998, Kazmi 2008). The term 'shrimp' is sometimes applied to smaller species, while 'prawn' is more often used for larger forms or this convention is even reversed in different regions. The Symposium of the Indo-Pacific Fisheries Council held in Tokyo in 1955 decided that the word 'prawn' should be applied to Penaeids, Pandalids, and Palemonids while smaller species belonging to other families should be referred to as shrimps (Chanda 2017). However, the study by Costa et al. (2003) shows that the term 'prawn' is used for all species belonging to the Penaeidae family. The Penaeidae family comprises 78 species falling under 17 genera and the *Penaeus* genus comprises the most commercially important species among penaeid prawns (Allan & Maguire 1992).

Prawn farming is becoming popular and it is believed that for the successful breeding of any animal, a basic fundamental understanding of its key biological processes are required (Krishna Menon 1965; Olele et al. 2012). This was further supported by (Tzeng 2007) in the sense that understanding the population's genetic structure is one of the essential components for the successful and sustainable long-term management of particular resources. In Bhutan, the National Centre for Aquaculture (NCA), Gelephu made a trial culture of a highly prized crustacean, the giant freshwater prawn (*M. rosenbergii*) in the year 2015 but no data were recorded from that trial.

Palaemonid and Penaeid prawns are important sources of proteins and are therefore considered as important resources for worldwide fisheries and aquaculture (Chan 1998). From a very early time, various kinds of prawns and shrimps have been known for their potential source of proteins (Chanda 2017). It has been reported by De Grave et al. (2008) that freshwater species are increasingly popular in the aquarium trades.

According to Sharma & Subba (2004) several researchers had made contributions to the taxonomy and distribution of freshwater and estuarine prawns and marine shrimps but still there is an information deficit pertaining to the taxonomy and diversity of prawns. It was also confirmed by Tzeng (2007) that very little work has been done on prawn taxonomy and diversity. This gives an opportunity for young enthusiastic researchers to explore beyond what has been documented. There are a handful of studies on prawns and shrimps from neighboring countries like India, Nepal and Bangladesh but no clear documentation of the species has been made in Bhutan. So the current work lays emphasis on the diversity of species present and their distribution in the territorial regions of Southern Bhutan.

2. Materials and methods

2.1. Study site

Zhemgang Dzongkhag lies in the south-central region of the country. It is a part of the wildlife corridor constituting the famous Royal Manas National Park, Jigme Singye Wangchuck National Park, and Phrumshingla National Park. The proposed study site, Ngangla gewog, lies in the extreme south sharing some international boundaries with India (Figure 1). It lies at an altitude of 150–1600 m.a.s.l and has an area of 315 sq km. It has an average annual temperature of 16°C with an average annual mean precipitation of 2600 mm. The selected stream for the study is one of the small tributaries that joina major river, Manas. The proposed study site lies within the boundary of Ngangla Gewog (coordinates: 26°51′9.33″N and

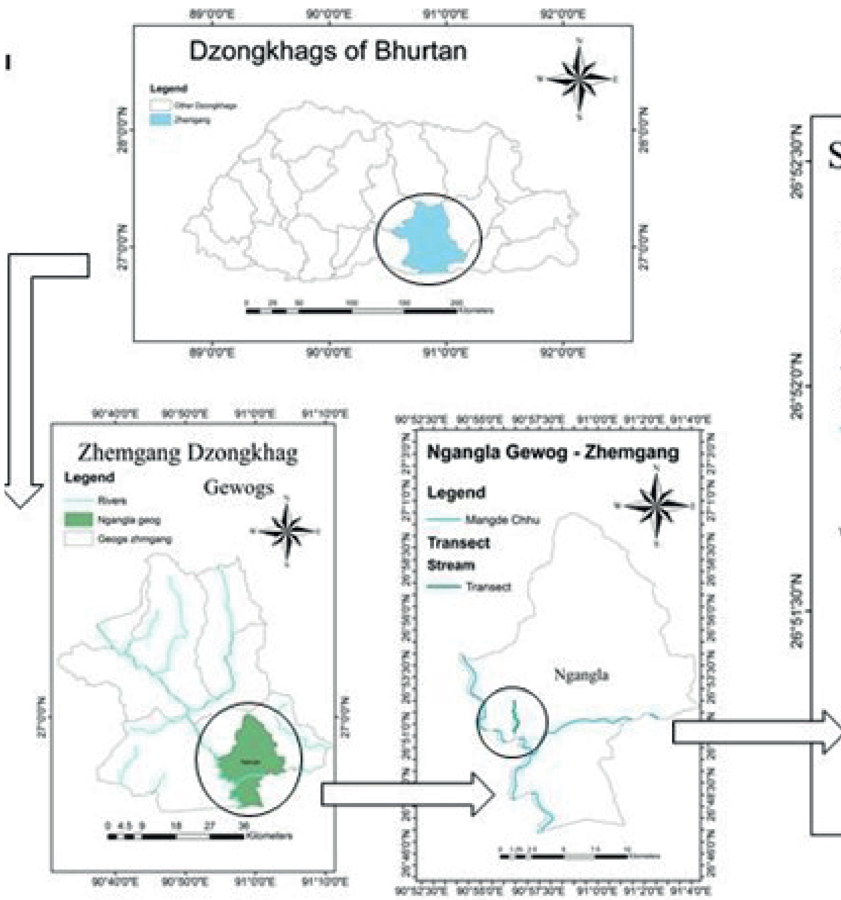

Figure 1

Map showing the site for the present study

90°56'30.34"E) and an elevation of 210 m.a.s.l. The current study was carried out in December 2019 to January 2020.

2.2. Data collection and sampling technique

After a preliminary survey, transect had been laid along the stretch of the stream, each plot laid on the stream transect was located at an interval of 100 m with a plot size of 5 m stretches along the stream covering the whole width of the stream. The prawns were collected systematically in each plot by using the kick method which involves disturbing the area slightly above the nets so that it directly encourages the invertebrates to move toward the target location. The samples were collected using dip nets and, in some cases, direct hand-picking was involved. The collected specimens were placed on a beating tray for identification and a few morphological measurements. The collected specimens were recorded by labeling the unidentified specimens, which were preserved in 70% ethanol.

2.3. Study method and sampling design

According to (Chan 1998), the specimens were randomly collected from different locations within the study area. On the other hand, (Olele et al. 2012, Lima et al. 2014) used a systematic sampling technique that involves a collection of specimens from the same designated location over an extended time period. So, in this study, the sampling plot was laid out along the stream at a distance of 100 meters using ArcGIS software. In order to make it more systematic, the specimens were collected from a sample stretch of 5 m along the stream covering the whole width of the stream. The velocity of the stream was measured using the velocity float method. In this method, the duration of the floating object was measured at a certain fixed distance. The particular plot was classified according to standards made by (Jowett 1993), which classify streams into ponds (< 0.2 m s^{-1}), runs, (0.2 – 0.6 m s^{-1}), and riffles (> 0.6 m s^{-1}).

The morphological features were measured using digital calipers and then fixed in 10% formalin for subsequent preservation in 70% alcohol along with a label placed inside a jar (Raghunathan & Valarmathi 2007, Purohit & Vachhrajani 2018, Rath et al. 2016). As mentioned by Sharma & Subba (1970) and Raghunathan & Valarmathi (2007), a few specimens were preserved in 5% formalin for further study.

2.4. Statistical tools and diversity indices

The collected data was employed for the statistical analyses to find the species diversity, abundance, and similarity in different habitats and different communities. Shannon's Diversity Index, Pielou's Evenness, and Margalef's Richness were used to analyse the diversity, species evenness and richness respectively. Berger-Parker's Dominance index was used to find the most dominant species.

Shannon-Wiener Index (H')

$$H^{'} = -i = 1SPi \times Ln(Pi)$$

where: $Pi = Ni/N$ (relative abundance of each species, or proportion), Ni = no. of individuals in species i, N = total number of all individuals

Margalef's Richness Index (D_{mg})

$$D_{mg} = (S-1)Ln(N)$$

where: S = Total number of species, N = Number of individuals

Pielou's Evenness Index (J)

$$J = \frac{H'}{H_{\cdot}}$$

$$J = -i = 1SPi \times Ln(Pi)Ln(S)$$

where: H' = Calculated Shannon-Wiener diversity, H_{max} = $Ln(S)$ [species diversity under maximum equitability conditions], S = Total number of species

Species similarity

Species similarity between two communities was calculated according to Sorenson's index: (QS)
where: J = number of similar species in both

$$(QS)QS = 2J(a+b)$$

communities, a = total number of species in community A, b = total number of species in community B.

The value of QS ranges from 0 to 1. With this index, 0 represents no similarity and 1 complete similarity. In other words, the larger the value, the greater the similarity.

Other statistical tools

Cluster analysis was performed to find the freshwater prawn assemblages among different sampling habitats using Sorenson's and Bray-Curtis' similarity index, which considers the number of the species in the communities. The analysis was performed using PC-ord.

A normality test for diversity, richness, and evenness was conducted using Shapiro-Wilk's test in the Statistical Package for Social Science (SPSS). A Kruskal Wallis test was performed to check the significant differences in species diversity, abundance, richness and evenness between different habitat types. Furthermore, Spearman's correlation was carried out to check the correlation between the prawn's abundance and physiochemical parameters of water. It was also used to see the correlation between different water parameters such as pH, DO (dissolved oxygen), salinity, conductivity, TDS (total dissolved solids) and temperature in relation to the numbers of individuals found in the sampling plot.

3. Results

3.1. Species composition

A transact for the study was laid in a stream, which altogether totalled 30 plots. A total of 243 individuals were recorded from the study area belonging to two families and four genera. The lists of species recorded were *Macrobrachium lar* f (Fabricius 1798), *M. rosenbergii* (De Man 1879), *M. equidens* (Dana 1852), *Penaeus merguiensis* (De Man 1888), *P. japonicas* (Bate 1888), *P. monodon* (Fabricius 1798), *P. latisulcatus* (Kishinouye 1896), *P. longistylus* (Kubo 1943), *P. indicus* (Edwards 1837), *P. semisulcatus* (De Hann 1850), *Penaeopsis rectacuta* (Bate 1881), *Metapenaeus dobsoni* (Miers 1878), *M. insolitus* (Racek and Dall 1965) in Chan 1998 (Table 1).

3.2. Relative abundance of species

Macrobrachium lar (RA = 13.58%) was the most abundant species found in all sampling regions followed by *Peneaus semisulcatus* (RA = 12.35%) and *M. equidens* (RA = 10.70%) (Figure 2). *P. indicus* (RA = 2.47%) and *Metapeneaus insolitus* (RA = 2.47%) were the scarcest species found in the area.

Table 1

Abundance ranking of prawns in the study area

Species	Counts	Species Ranking	Relative Abundance (%)
Macrobrachium lar	33	1	13.58
Penaeus semisulcatus	30	2	12.35
Macrbrachium equidens	26	3	10.70
Penaeus longistylus	24	4	9.88
Penaeus merguiensis	22	5	9.05
Penaeus monodon	21	6	8.64
Penaeus latisulcatus	20	7	8.23
Penaeopsis rectacuta	17	8	7.00
Macrobrachium rosenbergii	16	9	6.58
Penaeus japonicas	12	10	4.94
Metapenaeus dobsoni	10	11	4.12
Penaeus indicus	6	12	2.47
Metapenaeus insolitus	6	13	2.47

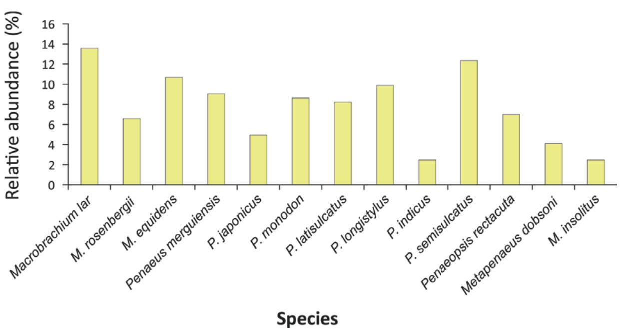

Figure 2

Relative abundance of prawns found in the study area

A total of 243 individuals of prawns were recorded from the sampling region. The analysis of the specimens showed a representation of 13 species of 4 genera and 2 families. The pie chart (Figure 3) shows that the Penaeidae family (N = 168, RA = 69%) was more dominant than Palaemonidae (N = 75, RA = 31%) in the entire sampling area. The Penaedae constituted almost 2/3rd of the total recorded individuals. There were 10 species from the Penaeidae family which altogether amounted to a larger number, while the Palaemonidae family made up the remaining three numbers.

Similarly, this pie chart (Figure 4) reveals that the *Penaeus* genus (N = 135, RA = 55.6%) was the most abundant genera of prawns in the study site followed by *Macrobrachium* (N = 75, RA = 30.8%) followed by *Penaeopsis* (N = 17, RA = 7%) with *Metapenaeus* (N = 16, RA = 6.6%) being the scarcest genera found at the sampling site.

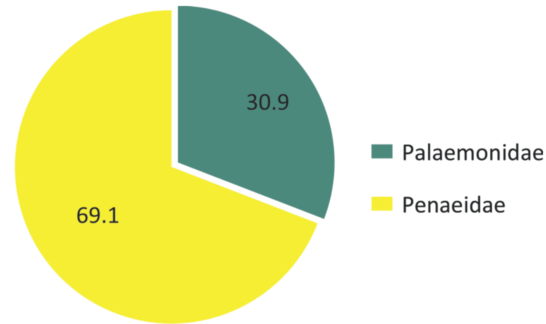

Figure 3

Pie-chart showing relative abundance of two prawn families

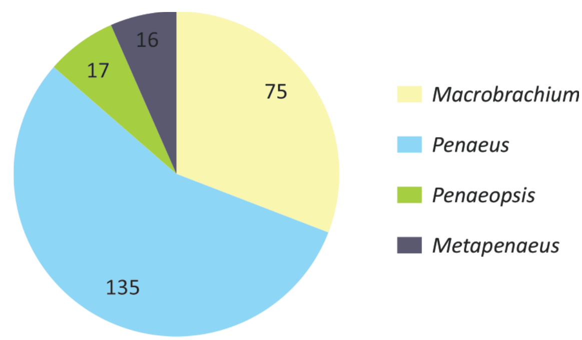

Figure 4

Pie-chart showing the relative abundance of genera in prawns

3.3. Species ranking

The overall ranking of 13 prawn species according to their relative abundance showed that they were distributed into 13 ranks (Table 1). The maximum abundance was noted for *M. lar* (N = 33, RA = 13.58%) followed by *P. semisulcatus* (N = 30, RA = 12.35%) and *M. equidens* (N = 26, RA = 10.70%), and so these species were ranked 1, 2, and 3 respectively. The remaining 10 species ranked between 4 and 13 together accounted for about 63.37% of the total abundance. *P. indicus* (N = 6, RA = 2.47%) and *Metapenaeus insolitus* (N = 6, RA = 2.47%) were the least abundant species found within the entire sampling region with the same number of individuals found.

Figure 5 shows that *M. lar* (n = 12) and *P. semisulcatus* (n = 12) was noted to be the predominant species in the area followed by *M. equidens* (n = 10) and *P. merguiensis* (n = 10), ranked the 2nd most frequently occurring species in the sampling plot. The species *P. japonicas* (n = 3) and *P. indicus* (n = 3) both were the scarcest in the three plots of the total study area.

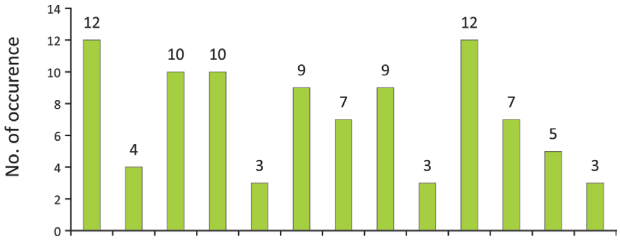

Figure 5

Chart showing total species in the study area

It was observed that more prawns were found in the ponds (n = 200, RA = 82%) than in the runs (n = 31, RA = 13%) and riffles (n = 12, RA = 5%) (Figure 6).

3.4. The overall diversity of prawns

The overall diversity of prawns was computed along with the evenness and richness of the study area (Table 2). The study area had an overall diversity of H' = 2.3035, richness (D_{mg} = 2.3645), and evenness (J = 0.8981), which indicates that the species are diverse and evenly distributed.

Table 2

Overall diversity, evenness, and richness of the study area

Ngangla Gewog Zhemgang		
Shanon Diversity (H')	Margalef's Richness (D_{mg})	Pielou's Evenness (J)
2.45961	2.184574	0.958931

The diversity, richness, and evenness also differ among the habitats (Figure 7). Ponds have the most H' = 2.441, D_{mg} = 2.265, and J = 0.952, followed by runs with H' = 2.029, D_{mg} = 2.329, and J = 0.924, and, finally,

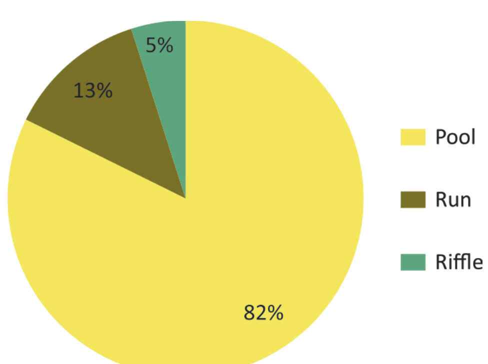

Figure 6

Pie chart showing the abundance of prawns in different habitat (water types)

riffles harbour the least with H' = 1.329, D_{mg} = 1.207, J = 0. 959. In all the studied habitats, ponds provide a better habitat for prawns.

The above bar graph shows there are some differences in the diversity of freshwater prawns in different habitats. To further justify this, the Kruskal Wallis test (Table 3) showed a significant difference in the diversity of freshwater prawns among different habitats, $H(2)$ = 6.254, p = 0.044. Similarly, there was a significant difference in species richness $D_{mg}(2)$ = 7.625, p = 0.022, and evenness $J(2)$ = 6.254, p = 0.044. This is confirmed by a study (Banerjee 2008) indicating that most prawns are found in water with weak currents, with sediments at the bottom of the water on which the prawns feed. This was also affirmed by Purohit & Vachhrajani (2018) that prawns tend to be found in stagnant types of water bodies.

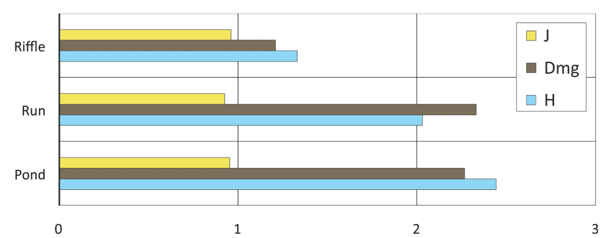

Figure 7

Bar chart showing diversity evenness and richness in different habitat types

3.5. Beta diversity

Sorenson similarity (QS) was used to assess the beta diversity of the sample habitats. The Sorenson ($F1$) scores between ponds and runs show the highest similarity index ($F1$ = 0.82) followed by ponds and riffles ($F1$ = 0.47). The runs and riffles have the lowest recorded similarity index ($F1$ = 0.46). This is further supported by the cluster dendrogram (Figure 8).

The cluster analysis was performed according to Sorenson-Bray-Curtis through the group average linkage method. Cluster cut-off was made at 75% information remaining. The cluster analysis showed that the ponds and runs have a diverse assemblage of freshwater prawns as compared to the riffles.

Table 3

Kruskal Wallis test for difference in diversity in different habitats

	Diversity (H')	Richness (D_{mg})	Evenness (J)
Chi-Square	6.254	7.625	6.254
Df	2	2	2
Asymp. Sig.	0.044	0.022	0.044

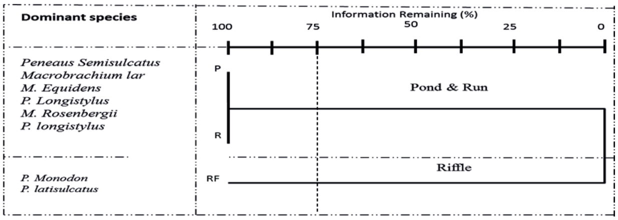

Figure 8

Cluster dendrogram showing similarities between sampling habitats

3.6. Distribution of freshwater prawns

The distribution of freshwater prawns in different habitats shows that three species (*P. semisulcatus*, *P. indicus*, and *P. monodon*) of the total prawns found were recorded in all habitats (Table 4). *M. rosenbergii, P. japonicas,* and *Metapenaeus insolitus* were recorded only in the pond habitat type, while *M. lar, M. equidens, P. merguiensis, P. longistylus, Penaeopsis rectacuta,* and *Metapenaeus dobsoni* were recorded in pond and run types of habitat. However, *P. latisulcatus* was the only species to be recorded in both pond and riffle habitats.

4. Discussion

From the sampling region, 243 prawn species were recorded. Among all species, *Macrobrachium lar* was the most abundant, and *P. indicus* and *Metapeneaus insolitus* were the most scarce in the area. Liu et al. (2007) confirm that the freshwater *Macrobrachium* genus of prawn is a group of highly diverse crustaceans known for its survival in a huge range of habitats in marine, freshwater and other water bodies. In addition, a total of 13 species of 4 genera and 2 families were recorded. Among them the Penaeidae family was more dominant, with a greater number of species, and comprised almost 2/3rd of the total recorded individuals; while the Palaemonidae family occupied the remaining three numbers. Similarly, a study by Samuel et al. (2016) on updated checklist of shrimps on the Indian coast reported that the Penaeidae family constitutes about 40% of the total recorded species while the Palaemonidae family was noted to have about 20% of the total recorded species. The other families comprise the remainder of the total recorded species from that study.

In terms of genus, *Penaeus* was the most and *Metapenaeus* the least abundant genera found at the sampling site. The study by Rath et al. (2016) on Penaeid and Palaemonid prawns in the Godavari Estuary in Andra Pradesh reported that the *Penaeus* genus was found more than Macrobrachium. Of the 13 prawn species, the maximum abundance was noted for *M. lar* followed by *P. semisulcatus* and *M. equidens*, respectively (Ballester et al. 2017). The genus *Macrobrachium* is the predominant genus in the Palaemonidae family and occurs in both marine and freshwater. The study by De Grave et al. (2008) showed that the *Macrobrachium* family is numerically the most dominant and the most common genus of Palaemonidea prawns.

The overall diversity values, including richness and evenness, indicate that the species are diverse and

Table 4

Distribution of freshwater prawns in different habitats

Species	Count	Habitat Types		
		Pond	Run	Riffle
Macrobrachium lar (Fabricius, 1798)	33	+	+	-
Macrobrachium rosenbergii (De Man, 1879)	16	+	-	-
Macrbrachium equidens (Dana, 1852)	26	+	+	-
Penaeus merguiensis (De Man, 1888)	22	+	+	-
Penaeus japonicus (Bate, 1888)	12	+	-	-
Penaeus monodon (Fabricius, 1798)	21	+	+	+
Penaeus latisulcatus (Kishinouye, 1896)	20	+	-	+
Penaeus longistylus (Kubo, 1943)	24	+	+	-
Penaeus indicus (Milne Edwards, 1837)	6	+	+	+
Penaeus semisulcatus (De Hann, 1850)	30	+	+	+
Penaeopsis rectacuta (Bate 1881)	17	+	+	-
Metapenaeus dobsoni (Miers, 1878)	10	+	+	-
Metapenaeus insolitus (Racek & Dall, 1965)	6	+	-	-
Total no. of individuals	243	200	31	12
Total no. of species	13	13	9	4

+ recorded, - not recorded

distributed evenly. Furthermore, these values differ according to diffrent habitats, where ponds have more overall diversity than runs, while riffles have the least. Similar conclusions were drawn from a study by Banerjee (2008), who made recommendations for farmers to breed prawns in paddy fields as they offer a suitable environment for prawns. It was further confirmed by De Grave et al. (2008) and Banerjee (2008) that most of the prawns are found in water with weak currents and featuring sediments on the bottom of the water on which the prawns feed. This was further supported by Purohit & Vachhrajani (2018), who found that the prawns are more likely to live in stagnant types of water bodies.

The similarity index according to the Sorenson (*F1*) score was the highest for ponds and runs, followed by ponds and riffles. It was reported by De Grave et al. (2008) that a greater number of species and individuals can be found in areas with slower water flow speeds. It has also been stated (De Grave et al. 2008; Banerjee, 2008; Purohit & Vachhrajani, 2018) that more species and individuals of prawns can be found in areas with slower water flow speeds. Therefore, all the species present in the run and riffle habitats were also present in the pond type of habitat so, the similarity index was higher for ponds.

5. Conclusion

This research was carried out to establish baseline information for future studies on freshwater prawns. A total of 13 species were recorded in four genera from two major families. The *M. lar* species was the most abundant, followed by *P. semisulcatus* and *M. equidens*. On the other hand, *P. japonicas, P. indicus* and *Metapenaeus insolitus* were the least dominant species occurring in the area. The *Penaeus* genus was the most common in the study area while the *Metapenaues* genus was the least abundant. Also, the diversity of freshwater prawns was found to be highest in ponds than runs and riffles.

5.1. Implications for conservation

There is no clearly documented work on prawns in Bhutan. As a result, there is a wide research gap on the taxonomy and diversity of prawns in Bhutan. This study would encourage future researchers to broaden their interest in discovering more about freshwater prawns to provide sufficient data for further conservational works. In addition, this study will help to establish a checklist and provide baseline data for prawn diversity, abundance, and distribution in the proposed study area. The present study focused on the abundance and diversity of freshwater prawns along a selected perennial stream and it will mark as a reference guide for future studies.

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Conflict of Interest

The Author(s) declare(s) that there is no conflict of interest.

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