Research Article

Diversity and Spatial Distribution of Freshwater Macro-Invertebrates in Poba Reserve Forest of Assam, India

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ABSTRACT

Seasonal investigation of aquatic macro-invertebrates in the aquatic bodies of Poba reserve forest (PRF) of Assam, India revealed altogether 55 species belonging to 29 families, 13 orders and five classes from three phyla *viz.*, Arthropoda, Annelida and Mollusca. Class Insecta was found to be the dominant taxa represented by six orders and 17 families that comprised 35 species (63.63% of the total species richness). Gastropoda was the second dominant class represented by the families *viz.,* Viviparidae, Ampullaridae, Pachychilidae, Thiaridae and Planorbidae, contributing with 17.24 % to the total 29 families. With two families (6.89%) class Bivalvia was represented by Unionidae and Cyrenidae families. On the contrary, the class Clitellata was comprised of only a single family and represented by the annelid *Hirudinaria manillensis*. Dytiscidae and Unionidae were found to be the dominant families comprised of seven species each, which contributed 12.72% to the total recorded species richness in the PRF. A spatial distribution pattern of the aquatic macro-invertebrate assemblages was observed during the study period. The highest abundance of macro-invertebrate species was recorded during the post-monsoon season (*N*=6148) proceeded by reduced abundance during the winter season (*N*=5101), pre-monsoon (*N*=4807) and monsoon season (*N*=4136) respectively. The present study is the first account of the freshwater macro-invertebrates diversity in the PRF which provides a piece of baseline information on the copiousness of different aquatic macro-invertebrate species of the reserve forest.

Key words: Anthropogenic activities, Aquatic macro-invertebrate, Core zone, Diversity, Insecta, Poba reserve forest.

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INTRODUCTION

Aquatic macro-invertebrates refer to the small organisms that have no internal skeletal system and live part or all of their lives in water. They comprise a diverse group of organisms that includes insects, annelids, molluscs and crustaceans that play an important role in aquatic ecosystems. Many of them are considered bioindicators and have the advantage of monitoring anthropogenic stress over a long period.[1]

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Small water bodies are important habitats at the catchment scale for many rare and declining freshwater organisms. For sustainable utilisation of freshwater systems the knowledge of the spatial distribution of water bodies, the variability of physico-chemistry and the contribution of each to catchment biodiversity is required. Freshwater ecosystems are becoming increasingly threatened by anthropogenic activities such as water pollution, habitat destructions, invasion by exotic species and non-point impacts mainly associated with land-use changes in inland aquatic systems.[2] The north-east region of the Indian subcontinent is one of the most significant biogeographic zones representing the transition zone between the Indian, Indo-Malay and Indo-Chinese biogeographic regions.[3] It forms a part of two of the 34 biodiversity hotspots listed by Conservation International, the Himalayas and Indo-Burma. The rich diversity of this region is attributed

due to the geomorphology, presence of hills, plateaus and valleys which creates a variety of torrential hill streams, rivers, lakes and Swamps.[4]

Aquatic bodies of Poba reserve forest (PRF) depicts one of the biodiverse habitats of freshwater macro-invertebrate faunal assemblages of the region which is hypothesized to species diversity and environmental heterogeneity of wetlands located in the western bank of Lali river, a tributary of the mighty Siang river of Arunachal Pradesh, and in the Assam-gateway, an important biogeographic corridor of India. It is the only natural forest and repository of varied forms of flora and fauna in the entire Jonai subdivision of Assam, India. Despite their apparent vulnerability, there is no published information on the diversity and distribution of macro-invertebrates in the freshwater systems of the reserve forest. Due to the practical importance of imperilled status worldwide and realizing the paucity of scientific information, the present investigation was aimed to study the diversity and distribution of aquatic macro-invertebrate assemblages of the pristine reserve forest and to establish a piece of baseline information of freshwater macro-invertebrate fauna of the PRF.

MATERIALS AND METHODS

The study was conducted seasonally (pre-monsoon, monsoon, post-monsoon and winter) in six sampling stations (Table 1) that comprised of three rivers and one lentic water body (lake) within PRF (27°50'11"N and 95°17'45"E) (Figure 1) for a period of two consecutive years 2018 to 2020. Kick nets and "D" framed nets were used for the collection of the specimens with a mesh size of 0.5–1 mm^2. Small specimens were carefully picked up from the net sampler using soft brushes and forceps. Sessile benthic species like molluscs were mostly handpicked using a 1 m^2 quadrate. Specimens were washed carefully and transferred to separate sample collection containers. Containers were properly labelled with site code and dates and finally brought to the laboratory and preserved in 80% ethanol for future references. Collected aquatic macro-invertebrates were identified based on morphological characters following standard identifying keys[5-13] along with the information available in the online databases *viz.*, WORMS, Molluscabase and International Union for Conservation of Nature (IUCN) etc. Further, the identified specimens were authenticated with the help of the Zoological Survey of India (ZSI) Kolkata, Shillong and Arunachal Pradesh.

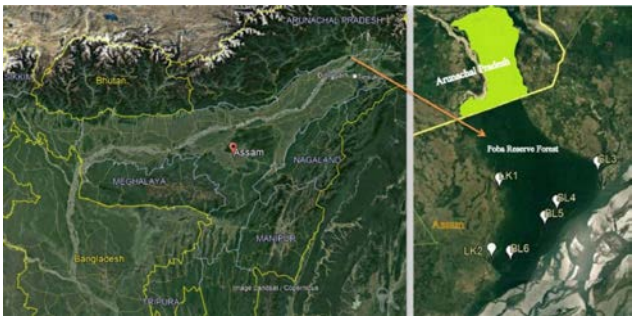

Figure 1: Satellite image of the study area (Poba Reserve Forest).

Table 1: Name, assigned code and co-ordinates of the sampling stations.

Aquatic bodies/River	Code	Latitude [N]	Longitude [E]
Leku River	LK1	27°49'21.2"N	95°16'52.1"E
Leku River	LK2	27°47'28.5"N	95°16'37.5"E
Sille River	SL3	27°49'48.1"N	95°19'53.4"E
Sille River	SL4	27°48'45.6"N	95°18'37.8"E
Hatmile beel	BL5	27°47'24.0"N	95°17'12.1"E
Oiyan River	BL6	27°48'20.4"N	95°18'15.3"E

Statistical analysis of data

Differences in local taxon richness among the different sampling stations were examined using a non-parametric ANOVA test. To evaluate the state of the diversity of macro-invertebrate fauna, different diversity indices *viz.,* richness (S), Simpson index (1-D), Shannon index (H), evenness index (EH/S) and the effective number of species (hill number) were calculated. All the analysis procedures were carried out using the software Paleontological Statistics (PAST, version 3.20) and Statistical Package for the Social Sciences (SPSS, Version 21) at a 0.05 significance level.

RESULTS

Altogether 55 species of aquatic macro-invertebrates belonging to 29 families, 13 orders and five classes from three phyla *viz.*, Arthropoda, Annelida and Mollusca were recorded during the study period (Table 2). Class Insecta was found to be the dominant taxa represented by six orders and 17 families that comprised of 35 species (63.63% of the total species richness). Gastropoda was the second dominant class represented by the families *viz.,* Viviparidae, Ampullaridae, Pachychilidae, Thiaridae, and Planorbidae, contributing with 17.24 % to the total 29 families. With two families (6.89%) class Bivalvia was represented by Unionidae and Cyrenidae families. On the contrary, the class Clitellata was comprised of only a single-family and represented by the annelid

Table 2: List of recorded aquatic macro-invertebrates found in the PRF and their taxonomic positions.

Phylum	Class	Order	Family	Genus/Species
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Laccophilus anticatus* (Sharp, 1890) *Hydatics fabricii fabricii* (Macleay, 1825) *Hydrovatus* sp. (Motschulsky, 1853) *Laccophilus indicus* (Gschwendtner, 1935) *Clypeodytes* sp. (Régimbart, 1894) *Cybister tripunctatus* (Olivier, 1795) *Cybister ventralis* (Sharp, 1882)
			Gyrinidae	*Dineutus* sp. (Macleay, 1825)
			Hydrophilidae	*Hydrophilus olivaceus* (Fabricius, 1781) *Laccobius* sp. (Erichson, 1837) *Helochares* sp. (Mulsant, 1844) *Enochrus esuriens* (Walker, 1958)
			Noteridae	*Neohydrocoptus* sp. (Satô, 1972) *Canthydrus laetabilis* (Walker, 1858)
		Hemiptera	Gerridae	*Gerris* sp. (Fabricus, 1775) *Ptilomera assamensis* (Hungerford,1965)
			Belostomatidae	*Lethocerus indicus* (Lepeletier and servile, 1825) *Diplonychus rusticus* (Fabricius, 1871)
			Nepidae	*Laccotrephes* sp. (Stal, 1865)
			Corixidae	*Ranatra filiformes* (Fabricius, 1790) *Micronecta haliploides* (Horvath, 1904)
			Hydrometridae	*Hydrometra* sp. (Latreille, 1797)
			Pleidae	*Plea liturata* (Fieber, 1844)
		Diptera	Chironomidae	*Chironomous* sp. (Megien, 1803)
			Culicidae	*Anopheles* sp. (Meigen, 1818) *Culex* sp. (Linnaeus, 1758) *Mansonia* sp. (Blanchard, 1901)
		Odonata	Libellulidae	*Diplacodes trivialis* (Rambur, 1842)
			Coenagrionidae	*Pantala flavescens* (Fabricius, 1798) *Brachythemis contaminate* (Fabricius, 1793) *Agriocnemis pygmaea* (Rambur, 1842) *Ceriagrion coromandelianum* (Fabricius, 1798)
		Ephemeroptera	Caenidae	*Caenis* sp.(Stephens, 1835)
			Baetidae	*Baetis* sp. (Leach, 1815)
		Trichoptera	Glossosomatidae	*Glossosoma* sp. (Curtis, 1834)
	Malacostraca	Decapoda	Potamonidae	*Barytelphusa* sp. (Alcock, 1909)
			Potamidae	*Lobothelphusa woodmasoni* (Rathban, 1905)
			Gecarcinucidae	*Sartoriana spinigera* (Wood-Mason, 1871)
			Palaemonidae	*Macrobrachium assamense* (Tiwari, 1958)
Annelida	Clitellata	Arhynchobdellida	Hirudidae	*Hirudinaria manillensis* (Lesson, 1842)
Mollusca	Gastropoda	Architanioglossa	Viviparidae	*Bellamya bengalensis* (Lamarck, 1882)
			Ampullaridae	*Pila theobaldi* (Hanley, 1875) *Pila globosa* (Swainson, 1822)
		Sorbeoconcha	Pachychilidae	*Brotia costula* (Brandt, 1974)
		Hygrophila	Thiaridae	*Tarebia lineata* (Gray, 1828)
			Planorbidae	*Indoplanoris exustus* (Deahayes, 1834)
	Bivalvia	Unionoida	Unionidae	*Parreysia corbis* (Hanley, 1856) *Parreysia corrugata* (Muller, 1774) *Parreysia smaragdites* (Benson, 1862) *Parreysia favidens* (Benson, 1862) *Parreysia lima* (Simpson, 1900) *Lamellidens marginalis* (Lamarck, 1819) *Lamellidens corrianus* (Lea, 1834)
		Veneroida	Cyrenidae	*Corbicula striatella* (Deshayes, 1854) *Corbicula assamensis* (Prashad, 1928)

Table 3: Diversity profile of recorded macro-invertebrates during the study period.

Diversity indices	Sampling Stations					
	LK1	LK2	SL3	SL4	BL5	BL6
Taxa (S)	35	40	43	46	48	28
Individuals (N)	3073	3026	3591	4259	4595	2409
Simpson index (1-D)	0.964	0.969	0.973	0.974	0.977	0.956
Shannon index (H)	3.418	3.561	3.685	3.743	3.826	3.216
Evenness index (E *H/S*)	0.871	0.880	0.927	0.917	0.956	0.890
Effective number of species (%)	86.45	87.90	92.16	91.50	95.00	88.46

Hirudinaria manillensis. At the family level, Dytiscidae and Unionidae were found to be the dominant families comprised of seven species each, which contributed 12.72% to the total recorded species richness in the PRF. It was also found that 17 families, *viz*., Gyrinidae, Corixidae, Hydrometridae, Pleidae, Chironomidae, Caenidae, Baetidae, Glossosomatidae, Palaemonidae, Gecarcinucidae, Potamonidae, Potamidae, Hirudidae, Viviparidae, Pachychilidae, Thiaridae and Planorbidae were represented by single species during the survey period (Table 2). Some photographs of the recorded macro-invertebrates are shown in Figure 5.

Species richness and diversity assessment of different sampling stations

Altogether 20,953 individuals were recorded from six sampling stations of the study area (Table 3). The maximum species richness (S=48) was registered from sampling station BL5 contributing 87.27% to the total recorded species of the study area whereas, sampling station BL6 had the minimum species richness (S=28) contributing only 50.90% to the total species richness (Table 3). Based on species abundance, sampling station BL5 was registered as the richest sampling station with a total of 4595 individuals during the entire study period followed by sampling stations SL4 (N=4259), SL3 (N=3591), LK1 (N=3073), LK2 (N=3026) and BL6 (N=2409) respectively (Table 3).

Coleoptera was the most dominant order with a contribution of 23.19% to the total recorded individuals of the study area, while the lowest contribution to the total abundance of aquatic macro-invertebrate species was recorded from the order Arhynchobdellida (1.14 %). The percentage contribution of other recorded orders *viz.,* Hemiptera, Diptera, Odonata, Ephemeroptera, Trichoptera, Decapoda, Architanioglossa, Sorbeoconcha, Hygrophila, Unionoida and Veneroida are 16.25%, 6.25%, 7.04%, 2.38%, 2.23%, 6.72%, 6.68%, 2.92%, 3.88%, 17.17% and 4.09% respectively (Figure 2).

Analysis of diversity indices in the sampling stations during the entire surveyed period is listed in Table 3.

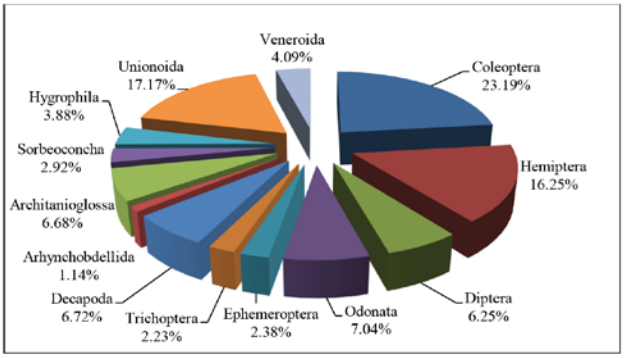

Figure 2: Pie diagram showing the percentage compositions of recorded macro-invertebrate orders during the study period.

The Simpson index (1-D) ranged from 0.956 (BL6) to 0.977 (BL5) and the Shannon index (H) ranged from 3.216 (BL6) to 3.826 (BL5) respectively. Evenness index (E *H/S*) shows a variation across the sampling stations with values ranging between 0.890 (BL6) and 0.956 (BL5) indicating a random distribution pattern of the freshwater macro-invertebrate assemblage in the study area. Analysis of the effective number of species revealed that sampling station BL5 had 95% of the species richness (S=48) were stable and evenly distributed; while LK1 had the lowest percentage of the effective number of species value (86.45%).

Seasonal and site-wise distribution of macro-invertebrate species

During the entire study period, the highest abundance (*N*=3724) of aquatic insects were recorded during the post-monsoon season and lowest (*N*=2441) during the pre-monsoon season. Similarly, for the classes Malacostraca and Clitellata highest abundance *viz*., *N*=405 and *N*=84 respectively were recorded during the post-monsoon season and lowest during the monsoon (*N*=316) and winter seasons (*N*=41) respectively. For the Gastropods and Bivalvia a low abundance was recorded during the monsoon season (*N*=562, *N*=765 respectively) and comparatively a high abundance was

observed during the post-monsoon season (*N*=841 and *N*=1258).

Observation on the site-wise distribution have shown that BL5 was registred as the richest sampling station (*N*=4595) with the highest abundance of aquatic insects (*N*=2643) followed by Bivalvia (*N*=844), Gastropoda (*N*=645), Malacostraca (*N*=379) and Clitellata (*N*=84). While, lowest abundance of aquatic macro-invertebrates were recorded in the sampling station BL6, with an abundance of Insecta, Bivalvia, Gastropoda Malacostraca and Clitellata of *N*=1468, *N*=431, *N*=328, *N*=155 and *N*=27 respectively.

DISCUSSION

Macro-invertebrates are the most diverse group of organisms inhabiting a variety of habitats. About 3% of them spend a part of their life in aquatic habitats in the form of larva (mosquitoes), pupa (water beetles), or as adults (annelids, molluscs).[14] Most aquatic faunal assemblage participates in ecological processes such as the decomposition of the organic matter, nutrient cycling and sediment bioturbation. They also control the density of other aquatic macro-invertebrates fauna by acting as a predator to them and as a food source for other groups of animals such as fish and to other aquatic groups. In India, about 5,000 insect species are estimated in various inland wetlands that are distributed heterogeneously.[11]

Usually, the Coleopterans are found associated with submerged aquatic vegetation and are predacious in nature.[15] Extensive work has been carried out by Vazirani on aquatic beetles of India such as Gyrinidae, Dytiscidae and Haliplidae.[16-18] In a similar study on the Dytiscidae family, three species *viz., Hydaticus fabricii*, *Dytiscus verticalis* and *Laccophilus anticatus* have reported from Pushkar Lake, Ajmer.[19] In the present study, the Dytiscidae family under the order Coleoptera was found dominant in the study area. Hydrophilidae was recorded as the second dominated family under the order Coleoptera and was represented by *Hydrophilus olivaceus*, *Laccobius* sp., *Helochares* sp. and *Enochrus esuriens* (Table 2). The investigation carried out by Khan and Ghosh[20] in 20 wetlands of West Bengal have reported 70 aquatic insects where order Coleoptera was the most dominant taxa followed by Hemiptera and Odonata. The present study also depicts the similar pattern [Coleoptera (23.19%) > Hemiptera (16.25%) > Odonata (7.04%)] for the three recorded insect orders (Figure 2).

Aquatic Heteroptera occupy a broad array of aquatic ecosystems and are adapted to a broad variety of niches.[21] The prevalence of hemipterans has been reported in the north-east region as well. The investigation carried out in an agricultural field of the Cachar district of Assam have reported 10 species of hemipterans.[22] In the present study, Hemipteran constituted 16.25% of the total recorded species during the study period (Figure 2). *Lethocerus indicus* (hemipteran) the giant water bug is a very popular edible macro-invertebrate and distributed in different parts of the country. Generally, this group feeds upon different types of aquatic fauna such as small insects, fishes, snails etc. The members of the Corixidae family are known as water boatmen as their legs resemble oars. Their mouthparts are generally unsuited for sucking or piercing. In the present investigation, two species *viz., Micronecta haliploides* and *Ranatra filiformes* were recorded under this family (Table 1).

Chironomidae and Culicidae were recorded under the order Diptera during the present study period. Chironomids, commonly known as midges, are one of the most widespread among the aquatic macro-invertebrates taxa occurring in all continents of the world. Worldwide approximately more than15, 000 species are recorded, exhibiting a wide array of habitat heterogeneity.[23] Due to the ubiquitous nature of these taxa, they are more often useful in biomonitoring of different aquatic ecosystems. The study on the diversity of aquatic insect fauna in the urban freshwater lakes of Tripura reported Culicidae as the most dominant family represented with 20.15% of the total insect abundance.[15] A similar pattern of the pre-dominance of the Culicidae family has also been reported in a lentic aquatic system.[24]

There are about 5,740 species of Odonata that are recorded globally, with 470 species under 19 families from India.[25] Libellulidae and Coenagrionidae are the most heterogeneous and the most successful among damselflies and dragonflies.[26] In the north-eastern region of India, studies of odonates started in 1979 by Lahiri.[27] He reported 33 species of odonates from various states of the north-eastern region such as Arunachal Pradesh, Assam, Manipur and Mizoram. In another study, 148 species of odonates have been reported from Meghalaya.[28] In the present investigation, the order Odonata was represented by two families *viz.,* Libellulidae and Coenagrionidae contributed 7.04% to the total macro-invertebrates abundance of the study area (Figure 2). The order includes the dragonflies and damselflies. Although the adults are terrestrial, the larvae are fully aquatic. They can play the role of predator in the food web and a model insect for analysis of the pollution status of aquatic habitats. Mayflies are prevalent in a particular habitat depending on the food type, space or habitats. It is reported that mayflies have

different adaptability of life cycle strategies ranging from a single generation to many in a year.[29] In an investigation altogether seventeen species of mayflies belonging to eight genera and five families in a stream of Meghalaya have been reported.[30] In our present study, we have recorded two species viz., Caenis sp. and Baetis sp under the family Caenidae and Baetidae respectively from the study area.

Members of the order Trichoptera are commonly known as Caddisflies are very sensitive to changes in environmental attributes. They are usually found associated with all substrate types and seepage areas.[31] In the present study, a single species, *Glossosoma* sp. was recorded from the study area. Barman and Gupta[32] reported two species of Trichoptera (*Hydropsyche bidens* and *Hydroptila* sp.) in the Bakuamari stream of Chakrashila Wildlife Sanctuary of Assam. Similarly, in another study, two species *viz., Glossosoma* sp. and *Diplectrona modesta* under Glossosomatidae and Hydropsychidae family respectively have been documented from the Majuli Island.[33]

The order Decapoda in the present investigation was represented by four families *viz.,* Potamonidae, Potamidae, Gecarcinucidae and Palaemonidae accounting for 6.72% of the total abundance of macro-invertebrates of PRF (Figure 2). In India, about 120 species of freshwater crabs (Potamonidae) have been reported so far and among these 38 species are from north-east India.[34] Generally, most freshwater crabs are endemic to narrow geographical regions and only a few have wide distribution and common occurrence. For instance, the crab species *Barytelphusa cunicularis* is a common freshwater crab distributed from Himachal Pradesh to Kerala.[34] On the other hand, *Sartoriana spinigera* is a very common freshwater crab in north-eastern parts of India and is frequently found in Bangladesh, Srilanka, Nepal, Myanmar and Pakistan[12] whereas, *Phricotelphusa elegans* and *Liotelphusa quadratic* are listed as vulnerable species and *Liotelphusa gageii*, *Maydelliathelphusa falcidigitis* are considered as near threatened.[12]

In the present study, a single species of aquatic leech (*Hirudinaria manillensis*) under the family Hirudidae was recorded during the survey period. Pathak *et al.,*[35] surveyed fifteen districts of Assam on the prevalence of aquatic and terrestrial leeches and reported *Hirudinaria manillensis* as the most dominant aquatic leech species during their study period.

Molluscs are one of the important ecological communities widely distributed in different types of habitats around the world except for Antarctica.[36] It constitutes the second-largest invertebrate assemblage and the most successful group next to class Insecta.[37] They are efficient assemblages in extracting and processing organic matter and its recycling in aquatic ecosystems. At the same time, many species of the malacofaunal community are highly sensitive to certain pollutants and anthropogenic impacts such as nutrient enrichment, availability of oxygen and changes in habitat structure.[38] Due to this inherent character, they are becoming well-suited sentinel organisms for studying the health of an aquatic ecosystem. Approximately 5,000 freshwater molluscs species have valid descriptions worldwide and an additional 10,000 undescribed molluscs species possibly exist on the global level.[39] In the eastern Himalayan region, about 74 bivalves and 112 gastropods species has been estimated to inhabit different aquatic bodies[40] which are approximately 2.86% of the total gastropods and about 6.12% of the total bivalve species estimated globally.[41] Out of the total globally recognized freshwater molluscs, about 8.12% of gastropods and 9.59% of bivalves are estimated to exist in the Indo-Burma biodiversity hotspots region.[42]

In the present study, we have recorded 15 species of freshwater molluscs (27.27% of total species richness) under two major classes *viz.,* Gastropoda and Bivalvia from five orders and seven families that are heterogeneously distributed in the water bodies of the PRF (Table 2). The present findings indicated the predominance of gastropods over Bivalvia. Gastropoda with five families contributed 18.51% to the total recorded families. On the other hand, Bivalvia with two families contributed only 7.40% to the total recorded families. The present findings of the gastropods predominance are corroborating with the findings of a previous study.[43]

Spatial distribution of aquatic macro-invertebrates in the study area

Freshwater habitats with a range of inhabitable water quality and prevailing substrate conditions usually support a wide array of macro-invertebrates assemblages with a reasonably balanced distribution pattern.[44] Different biotic and abiotic factors affect the abundance, distribution of species and the community composition of aquatic macro-invertebrates in an aquatic system. For instance, hydroperiod (dry and wet cycles), habitat complexity (absence or presence of aquatic vegetation), depth of habitat water and surface water quality play a major role in the distribution and assemblage of macro-invertebrates. Drying of wetlands and periodic flooding are also some of the most influential factors that affect the aquatic macro-invertebrates assemblage of an area.[45] In the present study, most of the sampling stations were

found affected by natural phenomena such as seasonal flooding and drying of the surrounding swamp covered areas etc. which may have a heterogeneous effect on the seasonal distribution of species across the sampling station of the study area.

It is noteworthy that, a spatial variation of aquatic insect's abundance was observed during the entire study period which is supported by the findings of Takhelmayum and Gupta[46] in the Loktak Lake of Manipur, India. The highest abundance of insects was recorded during the post-monsoon season (*N*=3724) proceeded by reduced abundance during the winter season (*N*=3388), monsoon season (*N*=2449) and pre-monsoon (*N*=2441) respectively (Figure 3). The findings of the present study indicating a high abundance of aquatic insects in the post-monsoon season are corroborated with the reports of Mukherji *et al.,*[47] who had reported the predominance of Coleoptera, Odonata and Diptera during the post-monsoon season while studying in some urban wetlands of Calcutta. The elevated abundance in the post-monsoon season may be due to the favourable conditions of physico-chemical attributes of the habitat waters and adequate food sources and shelter. During the pre-monsoon season, the reduction of aquatic insect's assemblage in the sampling stations may be attributed to the shrinkage of the habitat and decreased water level and thereby lack of inflow of adequate nutrients into the catchment areas. Biotic phenomena such as the emergence of adult insects in lotic water may also be a reason for the low abundance of macro-invertebrate during the monsoon season.[48] A similar phenomenon of low abundance in the monsoon season was also observed in the class Malacostraca, Gastropoda and Bivalvia (Figure 3). Besides, in the monsoon season, high water current and flooding of the adjacent area from the Laly River was frequently observed that might sweep away many macro-invertebrates species as indicated by the fact that high water current is inversely proportional to the macro-invertebrate species. Alternations of physico-chemical factors such as the increased load of suspended solids, low dissolved oxygen and high turbidity could have had a profound

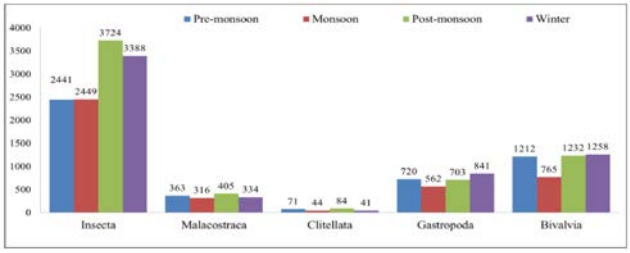

Figure 3: Bar diagram showing the seasonal distribution of macro-invertebrate classes during the study period.

effect on the abundance and density of aquatic fauna of the area. During the monsoon season, due to heavy rainfall of the region, the water level of aquatic bodies rises and reaches the adjacent area thereby increasing the sampling area. Thus, the expansion of the sampling area may also be one of the reasons for the low species encounter during the monsoon season.

Besides, the above mention factors, anthropogenic activities like cultivation, grazing and overexploitation of aquatic resources are also observed frequently during the season which may have a profound effect on the macro-invertebrates assemblage of the study area. Ethnic communities of the study area exploit different types of macro-invertebrates species such as molluscs, insects and crabs as a non-conventional food resource during the season. However, overexploitation alone can't be held responsible for the low abundance of species during the monsoon season. Some aquatic insect species are dormant for certain seasons of the year for instance the dormancy of Vellidae and Gerridae that has been reported by Naranjo *et al.,*[49] from the high altitudinal stream systems of Cuba. So dormancy of certain insects groups during the season may be one of the possible causative factors for the low abundance of macro-invertebrates assemblage during the pre-monsoon and monsoon season. For the molluscs species, comparatively a high abundance was observed during the pre-monsoon, post-monsoon and winter seasons (Figure 3). Low water current during the above mentioned seasons and shrinkage of the nearby water bodies might have favoured the high encounter of mollusc assemblage in the sampling stations of the study period. For the classes *viz.*, Malacostraca (eg. Crab spp.) and Clitellata (leeches), high water current during the monsoon season and hibernation during the winter season might be the causative factors for the low abundance during the study period. However, further in-depth studies will be required to establish whether other factors like life span and other environmental aspects affect the abundance and distribution of the aquatic macro-invertebrate species of the study area.

Observation on the general trend in the site-wise occurrence of aquatic macro-invertebrates in the PRF revealed that the maximum species richness and abundance were recorded in sampling sites BL5 (S=48, *N*=4595), SL4 (S=46, *N*=4259) and SL3 (S=43, *N*=3591) (Table 3, Figure 4). These sampling sites are located in the core region of the PRF for which less anthropogenic activities were observed. The sampling stations were observed with a combination of both aquatic vegetation and open water, which might be suitable and arise as the most prolific sampling stations

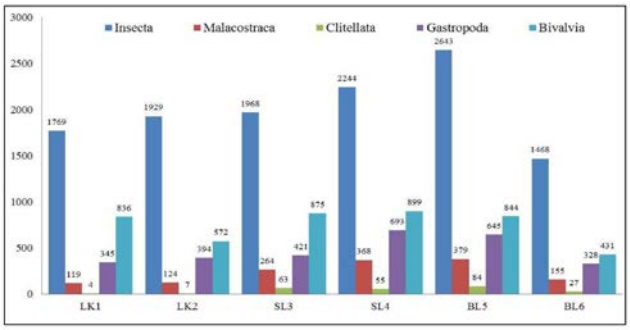

Figure 4: Bar diagram showing the site-wise distribution of macro-invertebrate classes during the study period.

for species growth and development since apart from providing shelter and food it allows successful avoidance from predators.

On the contrary, the sampling sites LK1 (S=35, *N*=3073); LK2 (S=40; *N*=3026) and BL6 (S=28, *N*=2409) were comparatively low in species richness and abundance (Table 3, Figure 4) which is located in the buffer zone of the reserve forest. The pervasiveness of agricultural activities, encroachment and grazing may be attributed to the low species count and abundance in these sampling sites. The bottom substrate of these water bodies was covered with a sandy bed with less aquatic vegetation. The water current was also comparatively high throughout the year which might be affecting the macro-invertebrate faunal assemblage of the sampling sites. Since many ethnic communities inhabit around the PRF frequently consume several varieties of edible aquatic macro-invertebrates as alternative protein sources during the lean period, so frequent and indiscriminate harvesting of aquatic resources cannot be ruled out as a cause of low species count in these sites. Thus, due to the cumulative effect of all these factors, the sampling stations (LK1, LK2 and BL6) have registered low species abundance during the study period.

Figure 5: Photographs of some recorded macro-invertebrates from PRF.

A-Damselfly larva (*Brachythemis* sp.), B-Dragonfly larvae (*Diplacodes* sp.),C-*Hirudinaria manillensis*, D-*Hydrophilus olivaceus*, E-*Dineutus* sp., F-*Diplonychus rusticus*, G,H- *Laccotrephes* sp., I-*Ranatra filiformes*, J-*Cybister tripunctatus*, K-*Sartoriana spinigera*, L-*Lethocerus indicus*, M-*Lobothelphusa woodmasoni*, N-*Barytelphusa* sp., O-*Macrobrachium assamense*, P-*Indoplanoris exustus*. Q-*Parreysia favidens*, R-*Parreysia corrugata*, S-*Pila globosa*, T-*Bellamya bengalensis*, U-*Brotia costula*, V-*Corbicula assamensis*, W-*Lamellidens marginalis*, X-*Lamellidens corrianus*, Y-*Tarebia lineata*

CONCLUSION

Despite the habitat heterogeneity, the occurrence of 55 species of aquatic macro-invertebrates under 29 families, 13 orders and five classes from three phyla *viz*., Arthropoda, Annelida and Mollusca depict the reserve forest as a suitable habitat for the freshwater macro-invertebrate population. Availability and high productivity of edible macro-invertebrates in the PRF promise a green prospect of rural economy through sustainable utilization of these bioresources provided a holistic approach of management and biodiversity conservation. This will especially help formulate conservation approaches in the near future. Certain crucial aspects such as the heterogeneity of the habitat, the effects of ecological and environmental conditions and their impact trends must be focused on with further comprehensive investigations to understand the distribution pattern of the macro-invertebrate species; which will help academicians and researchers for further

exploration of the various aspects related to freshwater macro-invertebrate species as a whole of the region.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

PRF: Poba Reserve Forest; **IUCN:** International Union for Conservation of Nature; **ZSI:** Zoological Survey of India; **SPSS:** Statistical Packages for the Social Sciences; **DFO:** Divisional Forest Officer; **sp.:** Species.

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