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Research Article

Ichthyo-faunastic assemblages and diversity in Pakke Wildlife Sanctuary of Pakke-Kessang District, Arunachal Pradesh

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ABSTRACT

An investigation was carried out in Pakke Wildlife Sanctuary (PWLS) to assess the fish diversity in protected areas (PA) in particular on the backdrop of increasing habitat susceptibility of lotic ecosystem of Arunachal Pradesh, India. The surveillances were conducted in five lotic water bodies in PWLS from 24th- 31st January, 08th- 12th March, and 4th-10th June, 2008 totaling a period of consecutive 20 days. The taxonomic enumeration of the sampled fish revealed the occurrences of a total 52 species belonging to 12 families and 34 genera. Analysis of population parameters unfolded conservation categories of threatened fish species, where *Amblyceps arunachalensis* and *Tor putitora* were endangered (EN), *Ompok bimaculatus*, *O. pabda* and *O. pabo* were near threatened (NT), and *Semiplotus semiplotus* was found vulnerable (Vu).This study also aims to validate adoption of 'Fish Conservation Park' for promoting eco-tourism and strengthening conservation endeavour in PAs of the state.

Key words: Fish diversity, Pakke Wildlife Sanctuary, Arunachal Pradesh, India

INTRODUCTION

The stabilization of ecosystems and protection of overall environmental qualities are essentially dependant on biodiversity accommodating intrinsic values of all species on the earth (Ehrlich & Wilson, 1991). However, increasing human population and abrupt rising of anthropocentric disturbances and degradations of lotic ecosystems has caused great destruction to the structure and function of stream biota (Stoddard *et al.* 2006) beyond restoration. Thus, the maintenance of fish diversity and management of pertinent habitat qualities have been considered as a great ecological issue alongwith challenges in the global scenario of present days. Hence, overall, biodiversity conservation becomes one of the major issues throughout the world and thus inland aquatic environments are gradually facing serious threats in terms of both diversity as well as stability. Lakra *et al* (2010) has opined the insistent necessity to build up research and systematic conservation plan for safeguarding freshwater biodiversity in its compatible habitat. Moreover, timely appraisal of habitat changes is essential at micro level which demands extensive survey and documentation before and after occurrences of cumulative changes of habitat (Lester *et al.* 1996; Dudgeon *et al.* 2006). Considering such increasing deterioration of the ecosystem and degraded biodiversity, government of India has declared many protected areas (PAs) such as wildlife sanctuaries, national parks and 'biodiversity hotspot' for safeguarding natural resources, a boon for all lifeforms.

The Eastern Himalayan Region is considered as one of the 36 biodiversity 'hotspot' areas of the world (Myers *et al*., 2000) where 60.93% of the region is covered by the state Arunachal Pradesh (26.28–29.30°N & 91.30–97.30 °E) of India. The area is characterized in having undulating mountains terrain ranging from low to high altitude that forms a huge network of freshwater drainages with numerous aquatic habitats. However, diverse developmental activities, increasing urbanization and changing landscape pattern, use of intensified fishing contraptions have already diminished many species in most of the lotic water bodies in Arunachal Pradesh (Chaudhry & Tamang 2007; Tamang & Shivaji 2012).Very recently in a case studies in Senkhi River in Itanagar wildlife sanctuary, Taro *et al.* (2022) reported water contamination and habitat degradation impacting drastic reduction of fish diversity and abundances. Similarly, a glimpse of indiscriminate electro-fishing was reported within D'Ering Wildlife Sanctuary (A news items of 'Arunachal Times', Vol, 24, dated 24.09.2020) revealed increasing anthropogenic pressure on wild fish stock even in PA. Similar case was also reported on illegal collection and export of highly expensive and rare ornamental fish *Channa barca* (Hamilton 1822) frequently by the poachers from Orang National Park in Assam.

Since the last 2 decades, the document on ichthyofaunal diversity of the state of Arunachal Pradesh as a whole, fairly been updated after the foremost compilation of 131 species by Nath & Dey (2000), followed by 213 species by Bagra *et al.,* (2009) and then 218 species by Darshan *et al*. (2019). After Darshan *et al.* (2019) twelve more new species have very recently been described and published totaling actually to 230 species inclusive of 69 new fish species described and incorporated since the pioneering endeavours of McClelland 1839.

Study area

Pakke Wildlife Sanctuary is the second largest next to Dibang wildlife sanctuary covering an area of 862 sq

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km and is located in the south-western part of Arunachal Pradesh guarded by Kameng River in the west and Pakke River in the east and on the Southern part of the reserve lays the Nameri National Park & Tiger Reserve, Assam (Figure 1). The sanctuary was previously located in East Kameng District (now in Pakke Kessang District) between the longitudes 92°35′ E and 93°51′ E and latitude 26°55′ N and27°15′N.The altitude inside the sanctuary varies from 100m in the southern boundary to 2040m in the northern boundary and is regarded as one of the zone with richest bio-diversity assemblage, comprised of several perennial rivers and streams on the Southern and the Northern part that drains either into Pakke, Nameri or Kameng rivers. In the South-Eastern part there are numerous named and unnamed nallas (small streams /natural runoff channels) which form the Pakke river system. The North-Western part has also numerous natural runoff channels originating in the

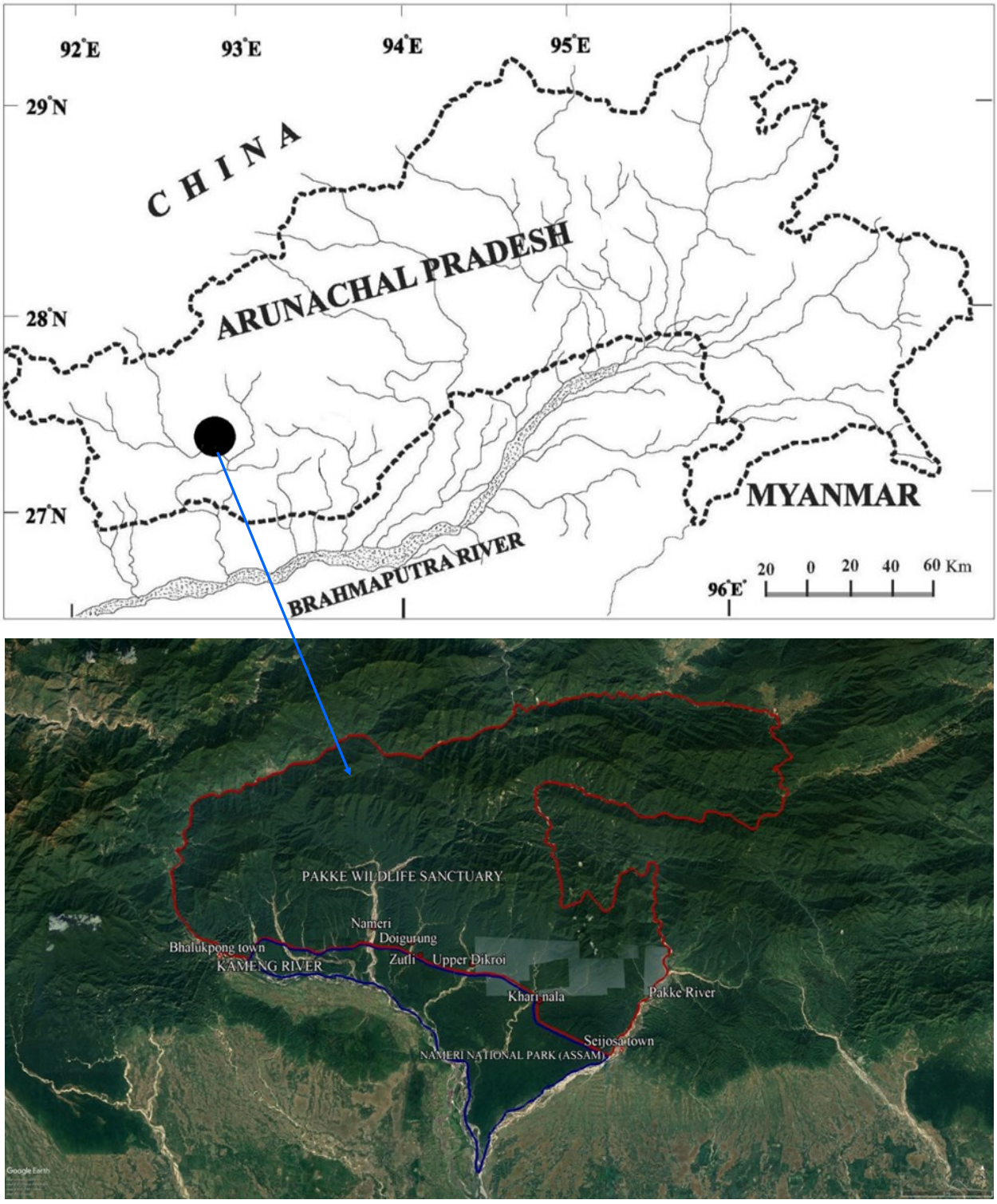

Figure 1. Map of Arunachal Pradesh showing the satellite map of Pakke Wildlife Sanctuary showing five study sites viz. Nameri River, Doiguring stream, Zutli nalla, upper Dikroi nalla and Khari nalla.

hills finally form a part of the Kameng river system. The sanctuary mainly consists of two types of habitats (i) most of the landed area is alluvial grassland and semi-evergreen forest patches (ii) while the aquatic area covering the sanctuary comprising of two major Rivers Nameri and Pakke with a network of small rivulets or nallas like Doigurung, Zutli, Butna, Upper Dikroi, Romari, Khari etc., separately confluences with Kameng River and finally merge with Brahmaputra River in Assam towards the south. Apart from these, there are several other water bodies like the Khari lake (approx. 1.2 ha) and are extensively used by wildlife of the sanctuary. The study was conducted covering five lotic water bodies viz., Nameri River, Doigurung stream, Khari nalla, Upper Dikroi nalla and Zutli nalla for 20 consecutive days.

The PWLS, in reality possess adequate water catchment area including both lotic and lentic habitats and seasonal runoffs. Inspite of these, hardly any attempts were made earlier to document ichthyo-faunastic assemblages in this protected area. So far, Vishnupriya Sankararaman (2012) has reported 30 species of fishes (unpublished data). Of these, only 8 species were traditionally identified and remaining species up to genus level. Thereafter, no systematic fish inventory report has so far been available from PWLS. Hence, in this study an attempt has been made to inventorize the ichthyofaunal diversity which has resulted enumeration of 52 fish species, and would be useful data base information for developing fish based ecotourism and policies for strengthening PAs based conservation strategies.

MATERIALS AND METHODS

A random fish sampling was undertaken over a period of 6 months from January to June, 2008 using recommended fishing tools and techniques (cast nets, drag nets, traditional devices, electro-fisher-Samus-725G, and sometime by barrier construction over diverted river courses).GPS-Garmin eTrex Legend was used for recording geographical coordinates and altitudes of each sampling site. The geographical coordinates of study sites were recorded between 26.98045ºN to 27.03978ºN and 92.77297ºE to 92.92058ºE with an elevation ranging from 129-175 m asl (Figure 1).The water parameter includes the variable dissolved oxygen, pH and temperature. Physical parameters of each study sites were observed and noted. Sampling of fish was carried out covering various microhabitats. The collected fishes were separated and quantified instantly in the spot. Initially, the specimens were preserved in 5% formaldehyde and later after clearing debris transferred to 10% formalin. The collected samples were brought to the laboratory of Rajiv Gandhi University for taxonomic identification and was confirmed following authentic literature sources Talwar & Jhingran (1991), Nath & Dey (2000) and Darshan *et al.* (2019) and subsequently deposited in Rajiv Gandhi University Museum of Fishes (RGUMF). Trophic niche of the species were identified following Taro *et al*.(2022).The conservation status of the encountered species was categorized following IUCN Red List of Threatened Species (2022-23). The riparian vegetations in the PWLS were sampled and identified following standard literatures (Bain & Stevenson, 1999; Jain & Rao, 1977; Nayar & Shastry, 1999) as well as based on the taxonomic records (Tana, 2023) of the Forest department, Govt of Arunachal Pradesh, India. The lotic water sample were collected and tested both in the field and laboratory following the method of Sunilkumar and Ravindranath (1998) and Sutherland (1996).

Data analysis

The fish diversity indices were calculated as per standard method (Shannon and Wiener, 1963) by the formula: H = -Σ (ni/N) log2 (ni/N), where, H = Shannon-Wiener index of diversity, ni = total numbers of individuals of a species and N = total number of individuals of all the species. Evenness of the species was calculated following Pielou's evenness index (Pielou's, 1966), i.e. J =*H'max/logS*, where: *H'max* = is the maximum value of Shannon-Wiener's index, and S = is the total number of species. The value of E falls between 0 and 1. The less variation in communities between the species, the higher would be the E value. Simpson's diversity index was calculated by the formula: D=1-(Σn(n-1)/N(N-1)), where D= Diversity, n= number of individuals of a single species, N= total number of all species. The Relative Abundance (RA) of each study site was calculated by dividing the number of individuals of a species by the total number of individuals of all the species multiplying by 100. All the diversity indices were performed using PAST software version 4. 02.

RESULTS AND DISCUSSION

The systematic list of fish species collected from five different sequential lotic water bodies along with their occurrence, distribution and abundance are presented in Table 1. The total ichthyofaunal diversity in the study sites were restricted to 52 species belonging to 12 families and 34 genera with a total catch of 4581 individuals. The catch composition of the fishes showed Cyprinidae as the dominant family contributing 44% (23 species), followed by Danionidae 11% (6 species), Bagridae, Nemacheilidae and Siluridae 7% (4 species) each, Channidae 6% (3 species), Amblycipitidae and Sisoridae 4% (2 species) each and finally Badidae, Belonidae, Psilorhynchidae and Synbranchidae were found to be the least only contributing 2% (1 species) each (Table 1 and Figure 2). The quantitative analysis showed that among the 52 species, a hill trout *Opsarius barna* occurred to be the most abundant species (683), followed by *Bangana dero* (616), *Garra birostris* (456), *Garra annandalei* (365) and so on so (Table 1 and Figure 5). *Amblyceps apangi, Bangana dero, Neolissochilus hexagonolepis* and *Danio dangila* were commonly found in all five habitats. The catch abundances of *Bangana dero* (616) and *Neolissochilus hexagonolepis* (202) and their presence in all drainages indicated the fondness WLS as the preferred habitat for these sport fishes in particular. The highest species counts were documented in Doigurung (37 species), followed by Khari (35), Nameri (30), Upper Dikroi (18) and least in the Zutli nalla (12). In the context of diversity, Shannon -Weiner indices (H), were relatively higher in Khari (2.95), followed by Nameri (2.86) and other drainages of the PWLS whereas Pielou's evenness indices (J) were higher in Nameri (0.84) and Khari (0.83) with almost similar values, but lower in Doigurung (0.65).

Table 1. Checklist of fish species and number of individuals sampled from the different study sites along with their trophic niche and IUCN conservation status.

Sl. No	Fish species	Nameri	Doigurung	Zutli	Upper Dikroi	Khari	Total	Trophic niche	IUCN red list status
	Amblycipitidae								
1	*Amblyceps apangi* Nath & Dey 1989	20	3	2	9	23	57	Bottom	LC
2	*Amblyceps arunachalensis* Nath &Dey 1989	30	6	5	-	40	81	Bottom	EN
	Badidae								
3	*Badis badis* (Hamilton 1822)	-	-	-	-	13	13	Bottom	LC
	Bagridae								
4	*Batasio tengana* (Hamilton 1822)	5	-	-	-	-	5	Bottom	LC
5	*Mystus bleekeri* (Day 1877)	-	4	-	-	-	4	Column	LC
6	*Mystus montanus* (Jerdon 1849)	-	3	-	-	-	3	Column	LC
7	*Olyra longicaudata* McClelland 1842	-	10	-	-	8	18	Bottom	LC
	Belonidae								
8	*Xenentodon cancila* (Hamilton 1822)	-	2	-	-	-	2	Column	LC
	Chaniidae								
9	*Channa gachua* (Hamilton 1822)	4	7	-	-	-	11	Column	LC
10	*Channa pomanensis* Guruma-yum& Tamang 2016	-	2	3	-	-	5	Column	Nev
11	*Channa punctatus* (Bloch 1793)	3	6	-	-	4	13	Column	LC
	Cyprinidae								
12	*Bangana dero* (Hamilton 1822)	188	149	1	165	113	616	Bottom	LC
13	*Barilius vagra* (Hamilton 1822)	20	-	-	-	40	60	Column	LC
14	*Botia rostrata* Gunther 1868	-	5	-	4	81	90	Bottom	LC
15	*Chagunius chagunio* (Hamilton 1822)	150	1	-	10	9	170	Bottom	LC
16	*Semiplotus semiplotus* (McClelland 1839)	25	2	-	10	80	117	Bottom	Vu
17	*Garra annandalei* Hora 1921	112	131	-	-	122	365	Bottom	LC
18	*Garra arupi* Nebeshwar et al. 2009	119	-	-	104	98	321	Bottom	Nev
19	*Garra birostris* Nebeshwar & Vishwanath 2013	152	161	-	-	143	456	Bottom	Nev
20	*Garra kalpangi* Nebeshwar et al. 2012	12	-	-	-	5	17	Bottom	Nev
21	*Garra lissorhynchus* (McClelland 1842)	63	29	-	-	69	161	Bottom	LC
22	*Labeo pangusia* (Hamilton 1822)	-	3	-	-	-	3	Bottom	NT
23	*Neolissochilus hexagonolepis* (McClelland 1839)	88	10	4	50	50	202	Column	NT
24	*Oreichthys cosuatis* (Hamilton 1822)	-	9	12	-	11	32	Column	LC
25	*Oreichthys crenuchoides*Schäfer 2009	-	1	-	3	-	4	Column	DD

26	*Osteobrama cotio* (Hamilton 1822)	1	-	-	-	-	1	Column	LC
27	*Pethia conchonius* (Hamilton 1822)	-	-	-	-	6	6	Column	LC
28	*Pethia guganio* (Hamilton 1822)	-	1	-	-	-	1	Column	LC
29	*Pethia ticto* (Hamilton 1822)	-	7	-	12	-	19	Column	LC
30	*Puntius chola* (Hamilton 1822)	-	6	-	-	-	6	Column	LC
31	*Puntius sophore* (Hamilton 1822)	-	12	-	9	-	21	Column	LC
32	*Raiamas bola* (Hamilton 1822)	15	3	-	-	5	20	Column	LC
33	*Tariqilabeo latius* (Hamilton 1822)	-	-	-	-	2	2	Bottom	LC
34	*Tor putitora* (Hamilton 1822)	8	3	-	-	-	11	Column	EN
	Danionidae								
35	*Danio dangila* (Hamilton 1822)	56	24	62	29	31	202	Column	LC
36	*Danio rerio* (Hamilton 1822)	41	-	-	38	48	127	Column	LC
37	*Devario aequipinnatus* (McClelland 1839)	15	1	1	1	2	20	Column	LC
38	*Devario devario* (Hamilton 1822)	43	-	118	28	33	222	Column	LC
39	*Opsarius barna* (Hamilton 1822)	73	202	-	198	210	683	Column	LC
40	*Opsarius bendelisis* (Hamilton 1807)	51	5	2	5	2	65	Column	LC
	Nemacheilidae								
41	*Aborichthys uniobarensis* Nanda et al., 2021	30	-	5	6	25	66	Bottom	Nev
42	*Paracanthocobitis botia* (Hamilton 1822)	-	-	4	31	68	103	Bottom	LC
43	*Schistura beavani* (Günther 1868)	-	-	-	-	7	7	Bottom	LC
44	*Schistura devdevi* (Hora 1935)	10	-	-	-	16	26	Bottom	NT
	Psilorhynchidae								
45	*Psilorhynchus balitora* (Hamilton 1822)	18	4	-	-	5	27	Bottom	LC
	Siluridae								
46	*Ompok bimaculatus* (Bloch 1794)	-	3	-	-	-	3	Column	NT
47	*Ompok pabda* (Hamilton 1822)	-	2	-	-	-	2	Column	NT
48	*Ompok pabo* (Hamilton 1822)	-	5	-	-	-	5	Column	NT
49	*Pterocryptis indica* (Datta, Barman & Jayaram 1987)	3	-	-	-	1	4	Bottom	DD
	Sisoridae								
50	*Nangra assamensis* Sen & Biswas 1994	3	2	-	-	3	8	Bottom	LC
51	*Pseudolaguvia vespa* Praveenraj *et al.* 2021	5	1	-	-	3	9	Bottom	Nev
	Synbranchidae								
52	*Mastacembelus armatus* (Lacepède 1800)	-	47	-	-	39	86	Bottom	LC
	Total individuals	**1363**	**872**	**219**	**712**	**1415**	**4581**		

LC (Least Concern), DD (Data deficient), NT (Near Threatened), VU (Vulnerable), Nev (Not evaluated), EN (Endangered)

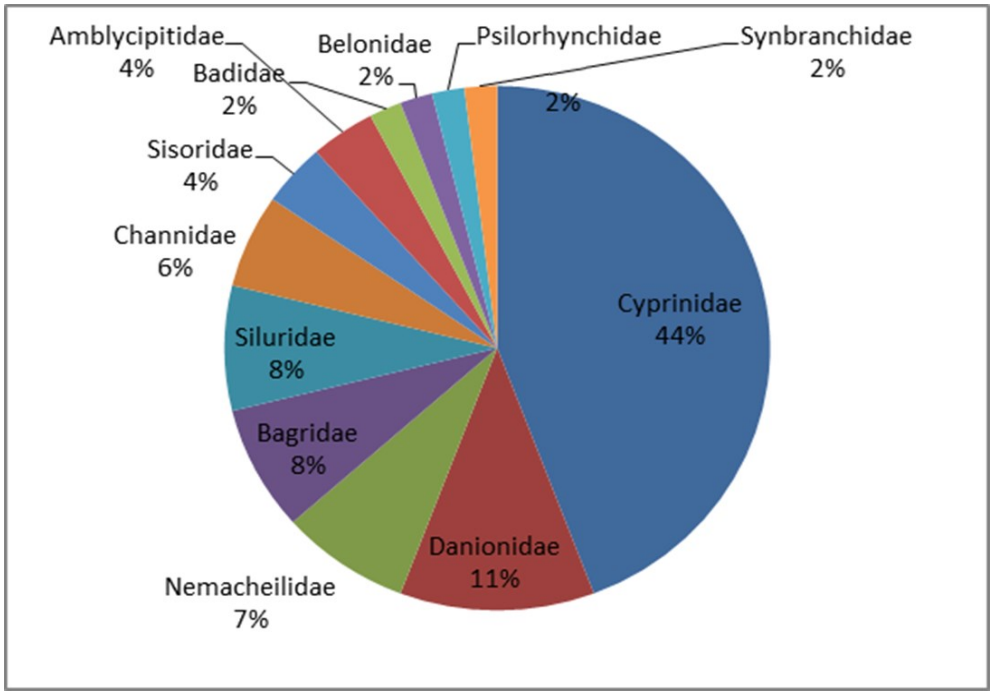

Figure 2. Abundances of different families of fish species in PWLS, Arunachal Pradesh

The IUCN conservation status represents that out of 52 species, majority i.e. 67% (35 species) belong to least concern (LC) category, followed by 11% (6) as near threatened (NT), 12% (4) as not evaluated (Nev), 4% (2) as data deficient (DD) and endangered (EN) each and 2% (1) as vulnerable (Vu) (Table 1 and Figure 3). The threatened species recorded were *Amblyceps arunachalensis* and *Tor putitora* (EN), *Ompok bimaculatus*, *O. pabda* and *O. pabo* (NT), and *Semiplotus semiplotus* (Vu). In the case of ecological trophic niche is concern, it is found that majority of the species were belong to bottom feeders represented by 48% (25 species), followed by 44% (23) column feeders and 8% (4) surface feeders (Table 1 and Figure 4).

The biodiversity indices are presented in Table 2 and depicted in Figure 6. As per the Shannon-Weiner diversity index, of the five study sites, three i.e. Nameri river, Doigurung stream and Khari nalla has higher species richness and population abundance i.e. 30 species (1363 individuals), 37(872), 35(1415) respectively than Upper Dikroi 18 species (712) and Zutli 12 species (219). Among these, species diversity was highest in Doigurung stream represented by 37 species, however uneven species assemblages have been indicated by lower values of Pielou's evenness index (0.65) compared to Nameri (0.83) and Khari (0.84). From the above facts, it would be interpreted that Khari and Nameri exhibited better habitat feature than Doigurung stream and other two lotic environments of PWLS. These were found well congruent with the values of Shannon diversity indices, where Khari stream depicted the value as 2.95, followed respectively by Nameri river (2.86), Doigurung (2.36), upper Dikroi (2.15) and lowest in the Zutli nalla (1.36). Accordingly Simpson's diversity indices also showed the similar patterns i.e. Khari and Nameri exhibited equal values (0.93) each followed respectively by Doigurung (0.86), Upper Dikroi (0.83) and Zutli (0.63).

Table 2. Diversity indices of fish species from different study sites.

Diversity parameter	Lotic Water Bodies				
	Nameri	**Doigurung**	**Zutli**	**Upper Dikroi**	**Khari**
Shannon's Diversity Index (H)	2.86	2.36	1.36	2.15	2.95
Simpson's Diversity Index (1-D)	0.93	0.86	0.63	0.83	0.93
Pielou's evenness index (J)	0.84	0.65	0.55	0.74	0.83
Species richness	30	37	12	18	35
Total individuals sampled (N)	1363	872	219	712	1415
Average population size	45.4	23.6	18.3	39.6	40.4
Relative Abundance (RA)%	2.20	4.24	5.47	2.52	2.47

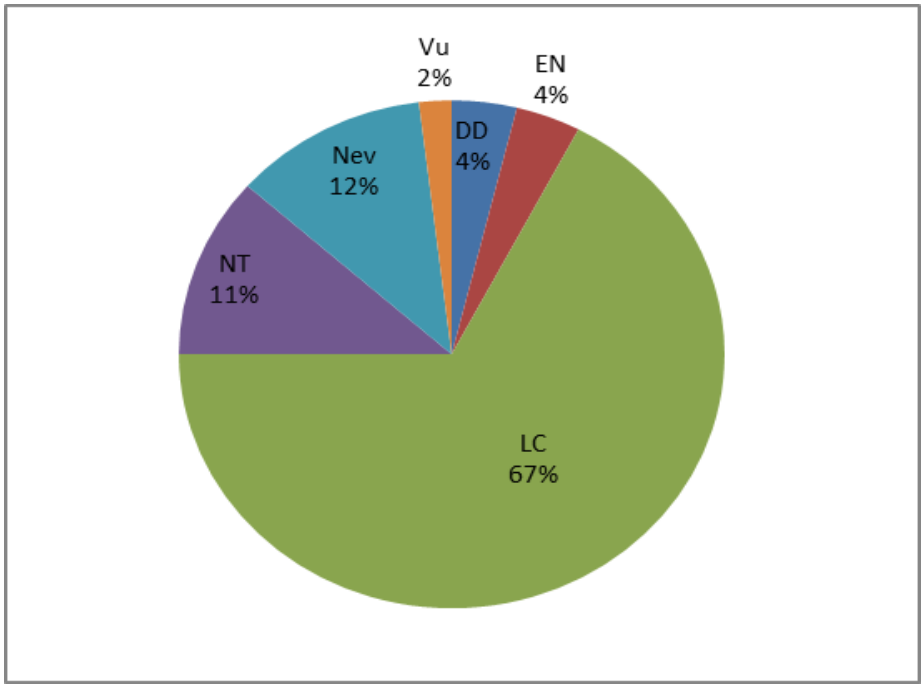

Figure 3. IUCN conservation status of all the available fish species in PWLS, Arunachal Pradesh

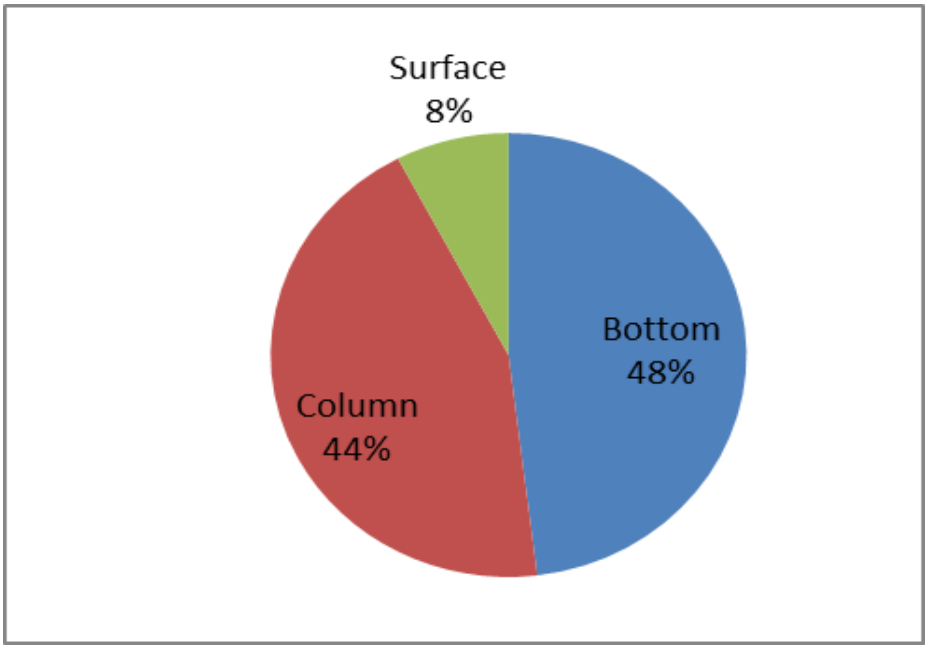

Figure 4. Trophic niche diversity of fish species encountered in PWLS, Arunachal Pradesh

ECOLOGICAL FEATURES OF RIPARIAN HABITAT IN PWLS

The five different study sites along with their habitat characteristics and patterns have been presented in Figure 7 (A-E). The valuing of the ecosystems services were found impact creating which have been evident from the work of Choudhury *et al*., (2016). The characteristics of ecological components are described as follows:

I. Vegetations

The identity of the vegetations was also found congruent with the findings of Tag *et al.* (2012) indicating that the vegetation exerts influence on aquatic ecosystem as well as other flora and fauna of the PWLS.

The riparian sites were comprised of semi-evergreen forests that includes species like *Bombax ceiba, Bischofia javanica (Urium), Canarium strictum (Kaladhuna), Dillenia indica (Outenga), Duabanga grandiflora (Khokun), Lagerstromia parviflora (Ajhar)* forming the upper storey. The next storey is represented by species of *Micromelum, Murraya, Randia, Meliosma,* and *Villebrunea*. These species are associated with dense clumps of *Phragmites, Saccharum, Alpinia allughas* and *Hedychium* species (*source:* Department of Environment & Forests, Govt of Arunachal Pradesh).

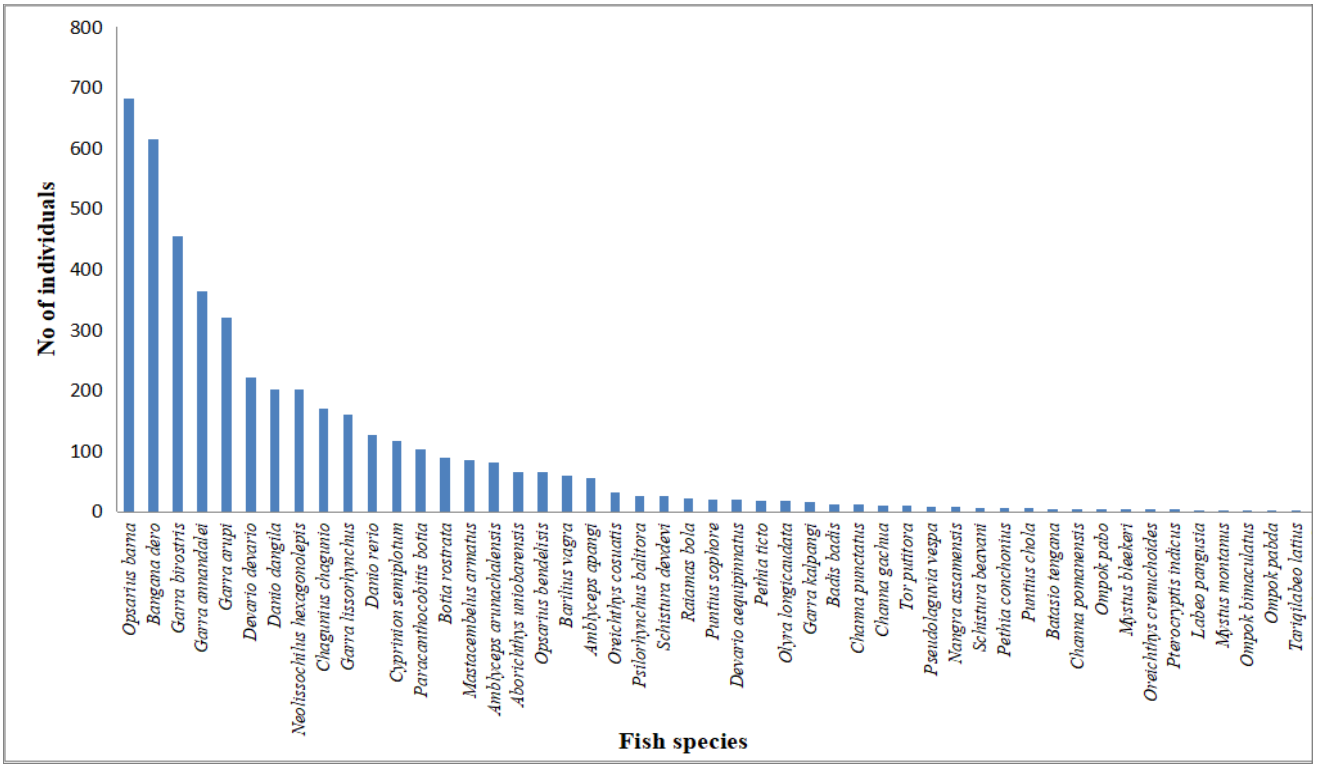

Figure 5. Comparative analysis of species abundances from five study rivers/streams. *Opsarius barna,* the highly dominant species followed by *Bangana dero, Garra birostris, G. annandalei, G. arupi, Devario devario*, *Neolissochilus hexagonolepis* and *Danio dangila* and rest of the species were drastically low in abundances.

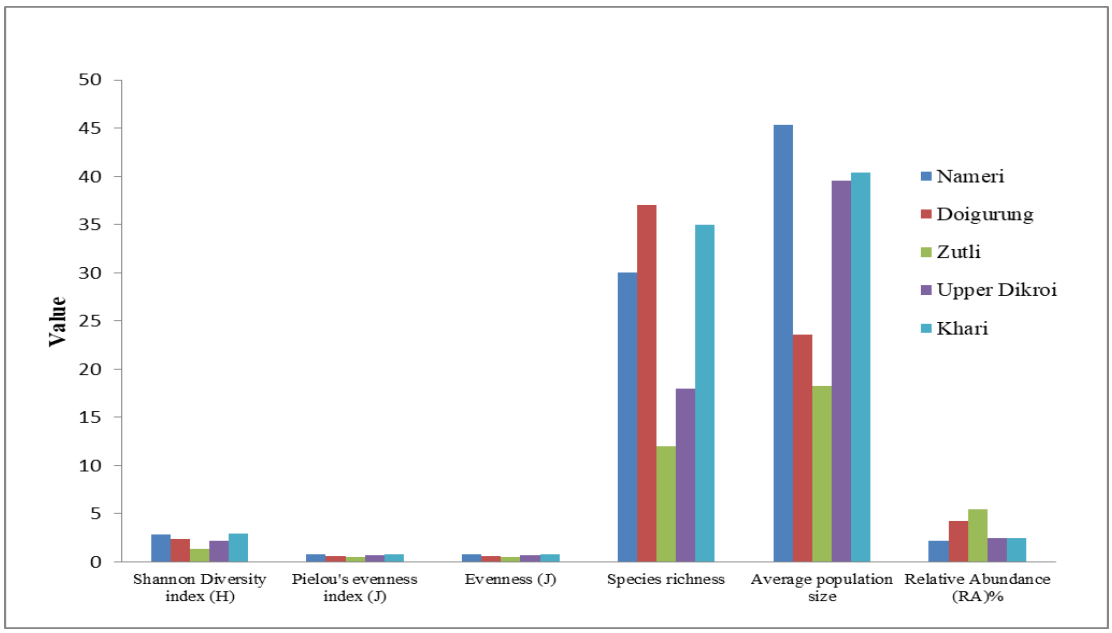

Figure 6. Species diversity and evenness indices within five lotic water bodies for fish at species level in PWLS, Pakke Kessang district, Arunachal Pradesh.

Freshwater fish assemblages are often structured by variables related to both water qualities and riparian vegetations (Gorman *et al.* 1978; Vannote *et al.* 1980; Penczak, 1995; Teresa & Romero, 2010). Accordingly the warmer waters have exhibited higher fish abundance and biomass while highly oxygenated waters might have led to greater species diversity (Mendonça *et al.* 2005; Murray *et al.* 2009; Warren *et al.* 2010). In addition, the distribution and composition of the fish species in any habitat have been found in close associations with various factors such as the availability of food, breeding sites, water current, depth, topography and physico-chemical properties of water (Harris, 1995). Besides the composition of riparian vegetation, most importantly it has also been observed that water volume, pressure and physical surroundings to be the major factors impacting fish diversity, distribution, abundance and predilection of altitude. Nameri is a widely spread River that comprises mainly of large to medium sized boulders with low concentration of sand (Figure 7A).These scattered boulders were seen to provide shelter and foraging microbahitat to bottom feeder fishes because running water in presence of sunlight enhances the algal growth and aggregates aquatic insects as food materials for fishes. It

A) Nameri River

B) Khari nala

C) Doigurung stream

D) Upper Dikroinala

E) Zutlinala

Figure 7. View of physical appearances and habitat patterns of different lotic sites.

has been practically seen that due to more available hiding spaces, huge water volume and torrential flow, fishes could not be catch in large number what we expected, and therefore richness value obtained were only 30 species. Khari stream consists mostly of moderate sized boulders, pebbles, cobbles, debris, and mud with moderate running water that enabled easy fishing either by drying water by constructing barriers over diverted water course or by battery operated electro-fishing. Hence, based on habitat characteristic and comfortable fishing condition, higher value of species richness (35 species) was obtained in comparison to Nameri (Figure 7B).The physical habitat of Doigurung was found somewhat similar to Khari particularly in substrate composition (Figure 7C) but water was slow moving due to more depth and wider spread than Khari nalla.These might have led to easy fishing using cast net and electro fisher leading to highest diversity from effective catch of 37 species, 2 species more than Khari stream. Upper Dikroi basically comprises of sands and small stones with narrow water passage, which probably was not preferable micro-habitat for diverse form of species. On account of presence of limited species specific spatial niche, low water quantity and situated at higher altitude (159 m asl) resulted lower richness of 18 fish species only (Figure 7D). Similarly Zutli nalla is comprised of submmersed boulders with mud and leaf litters and low water, unsuitable for those species that inhabit clear running water. So, lowest species richness with 12 species only was recorded (Figure 7E). Besides physical habitat structure, altitudinal gradients also exerted influence in fish species diversity among the sites of PWLS. Upper Dikroi and Zutli nalla are situated at the altitude of 159 masl and 175 m asl respectively which are higher than Nameri (129 masl), Doigurung (133 masl) and Khari (147 m asl).The diversity values of upper Dikroi and Zutli nalla were respectively lower with 18 and 12 species compared to Nameri (30), Khari (35), Doigurung (37). Hence it may be inferred that there existed inverse relationship between fish diversity and altitudes of water bodies with decreased species richness from lower to higher elevation region.

Table 3. Geographical coordinates altitudes, water parameters and atmospheric temperature of the selected lotic networks within Pakke Wildlife Sanctuary, Arunachal Pradesh.

Study sites	Location		Altitude (m)	DO (mg/l)	pH	Temperature	
						Atmosphere (ºC)	Water (ºC)
Nameri River	27.03978ºN	92.77297ºE	129	7.9±1.1	7.4±0.6	27.5±0.7	22.6±0.6
Doigurung stream	27.02787ºN	92.80651ºE	133	8.6±0.7	7.0±0.4	27.1±0.8	21.9±0.5
Zutlinala	27.01725ºN	92.81421ºE	175	8.4±0.5	5.9±0.3	24.7±0.5	21.5±0.7
Upper Dikroinala	27.01031ºN	92.86132ºE	159	8.5±0.4	7.3±0.8	20.2±1.0	17.4±0.6
Khari nala	26.98045ºN	92.92058ºE	147	8.9±0.4	7.0±0.9	17.8±1.1	16.9±0.7

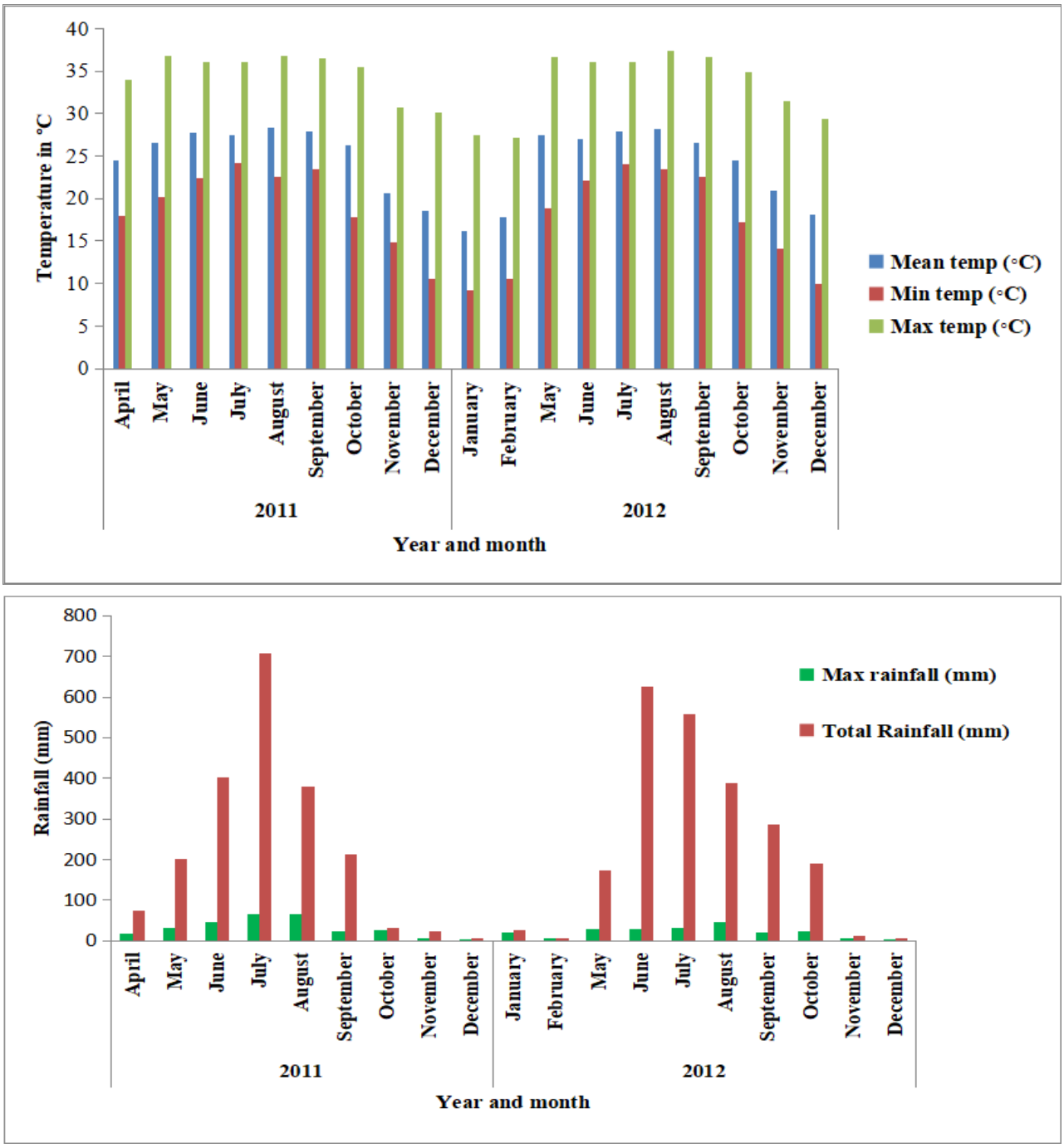

Figure 8. Average monthly temperature (°C) and rainfall data (mm) in Pakke Wildlife Sanctuary from April 2011 to February 2012 and May 2012 to December 2012. (Graph has been illustrated based on the data adapted from 'Reports of Department of Environment & Forests, Govt. of Arunachal Pradesh')

II. Lotic water quality parameters

All the water quality parameters are basically determining components having direct influence on habitat health for the fish and regulate population structure of aquatic life forms in general. Water of all study sites were clear, and slow to moderate flowing and somewhere stagnant. Water and atmospheric temperature were recorded ranging from 16.2 - 23.2 ºC and 16.7 - 28.2 ºC respectively, that indicated normal temperature ranges. Healthy water should generally have dissolve oxygen concentrations above 6.5-8.0 mg/L and most freshwater tropical fish do best at pH level within 6.8 and 7.8. The D.O showed the range with 6.8 - 9.3 gm/L and pH values ranged 5.6 –8.1 which indicates suitable water condition in general persisted in the lotic networks of PWLS.

III. Climate and rainfall patterns

As per the data from 1983 to 1995 recorded by the Tipi Orchid Research Centre, the average annual rainfall is 2500 mm. The mean (± SD) maximum temperature was 29.3°C (± 4.2) and the mean minimum temperature was 18.3°C (± 4.7). Most of the rainfall occurs between June and September (South-West monsoon), with some winter rain from December to February. March to May is hot, and some thunderstorms and showers occur in April-May. There were marked annual fluctuations in the total amount and the distribution of rainfall. The total number of rainy days varied annually from a low of 125 in 1997 to a high of 175 in 2003. The number of rainy days in each month varied from a mean of 2.125 days (1996-2004) in December to 25.6 days in June. Annual rainfall during 1996-2005 varied from 1778.3 mm in 1997 to 4174 mm in 2003. Maximum rainfall occurs during the months of June to August with about 500 mm rainfall in each of these months. Mean annual maximum temperature over a ten-year period was 29°C (± 1.97), while mean annual minimum temperature was 20°C (± 3.93). January is the coldest month with a mean minimum temperature of 14°C, while May to August was hot with mean maximum temperatures around 30-32°C. Between 1997-2000, mean annual relative humidity (in the mornings) was around 90%, with March being the driest month and June, the month with highest humidity. Mean annual relative humidity (in the evenings) was around 77% with March and June again being the least and most humid months respectively (Datta, 2001). The average monthly temperature (°C) and rainfall data (mm) of Pakke Wildlife Sanctuary from April 2011 to February 2012 and May 2012 to December 2012 are depicted in Figure 8.

CONCLUSION

Pakke Wildlife Sanctuary, being an important protected area under eastern Himalayan biodiversity hotspot, documentation on ichthyofaunal diversity was extremely necessary for status assessment and in future conservation perspective. The checklist of 52 fish species distributing over 12 families and 34 genera obtained from the study sites (Nameri River, Doigurung stream, Upper Dikroi and Zutli nalla) during a short period of time (20 days) would be of immense signifince to ichthyologists, conservationist, learners and management planners. The sanctuary itself would play a vital role as a ecosystem service provider if govt notifies it as aquatic "Conservation Park" and would be useful for imparting education, facilitating research, eco-tourism based development that nodoubt would pave the means of revenue generation in terms of sport fishing and related trades. The existence of some more fish species in the PWLS are expected from other inaccessible water bodies. Hence, the sanctuary need to be surveyed extensively for unfolding the more ichthyo-faunal assemblages. The water bodies in rainforests and various aquatic habitats are virginally responsible for up keeping of the aquatic food chain, fish diversity and population management. Though, the study also revealed frequent illegal fish catches in the major water bodies in PWLS like Nameri, Pakke and Kameng Rivers and are believed to be the cause of dwindling fish abundances even in this PA. Keeping view in this point, it is suggested to take up immediate possible measures at the govt. level rendering strict vigilance against fish poachers and adoption of awareness programme in fringe villages at least before causing irreparable damage to natural capital of the sanctuary.

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