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Research Paper

Ecology and ichthyofaunal diversity of Dirang Chu: a key Himalayan snow fed river of Arunachal Pradesh, India

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ABSTRACT

Arunachal Pradesh, a Himalayan state of India, is divided into five river valleys; the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these are fed by snow from the Himalayas and countless rivers and rivulets. The Dirang river valley resembles typical V-shaped valley of Himalayan terrain surrounded by denudation hills. The study embodies to carry out ecological and biological characteristics of the river Dirang, which harbor several important coldwater fish species like snow trout, loaches etc. in order to develop a suitable management plan for sustainable utilization of these Himalayan mountain resources. Physicochemical parameters of water such as dissolve oxygen content and temperature of Dirang river was found to be optimum for the habitat of coldwater fishes. The river water has relatively alkaline pH values ranging from 7.2 to 7.6. Phytoplankton density ranged from 3-40 individuals/l at various sampling sites, which was dominated by the members of Bacillariophyceae. Zooplankton density ranged from 3-27 individuals/l and Periphyton 60-120 individuals/cm^2. The river supports diverse fish species of which many are endemic to the region. Fish species like the *Schizothorax* sp, *Botia* sp, *Barilius bendelisis, B. bola, Punitus spp, Tor putitora, Danio spp., Garra spp., Gotyla gotyla, Anguilla* are found in the river drainage. Several spawning grounds of the coldwater species are also identified in the river valley which needs protection for conservation.

Key words: Arunachal Pradesh, Dirang river, Ecology, Icthyofaunal diversity

Arunachal Pradesh - the Land of the Rising Sun - with an area of 83,743 sq. km. is the largest state in the Northeastern region of India sharing international boundaries with Bhutan in the west, China in the north and Myanmar in the east. The population of Arunachal Pradesh is 10, 91,117 (2001 census). Forest covers about 82% area of the state and numerous turbulent streams, roaring rivers, deep gorges, lofty mountains, snow clad peaks and rich diversity of flora and fauna characterize the landscape. The climate varies from sub-tropical in the south to temperate and alpine in the north with large areas experiencing snowfalls during winter. The heights of the mountain peaks vary, the highest peak being Kangte (7090 above MSL) in West Kameng District. The state is divided into five river valleys; the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these are fed by snow from the Himalayas and countless rivers and rivulets (Sarma *et al*, 2012, 2016). West Kameng district is located in the western part of Arunachal Pradesh covering an area of 7422 km^2 accounts for 8.86% of the total area of the state. Its main land extends between 91^{o}30" to 92^{o}40" E longitudes and 26^{o}54" to 28^{o}01" N latitudes. Its northern boundary passes through the high peaks of the Himalayas that form the boundary between India and China (Tibet). The western boundary of the district demarcates Bhutan from India. The name of the district is derived from Kameng river, a tributary of the Brahmaputra, that flows through the district. Tenga, Bichom and Dirang Chu are the main rivers flowing through the district. All these rivers are tributaries of the river Kameng which flows through Bhalukpong circle of the district and joins the river Brahmaputra in plains of Assam.

The Dirang river valley resembles typical V-shaped valley of Himalayan terrain surrounded by denudation hills. Developments of terraces were observed at few locations along present river course on both sides of the river with an average elevation of about 5-15 m from the riverbed. In general both the banks of

the river are mostly covered with slope wash deposits with occasional bedrock outcrops. Major Geodynamic features observed along the left bank of the river are dormant slide zones with slope wash deposits and potential rock fall zones (Mahanta and Sarma, 2010). The study embodies to carry out the detail ecological and biological characteristics of the river Dirang, which harbor several important coldwater fish species like snow trout, loaches etc. in order to sustainable utilization of these high altitudinal Himalayan mountain resources.

MATERIALS AND METHODS

Field studies have been conducted for a period of one year during 2011-12 to analyze water quality, aquatic ecology and fish diversity. The existing data on water quality has been collected to evaluate river water quality on upstream and downstream of the river Dirang Chu. As a part of aquatic ecology, phytoplankton, zooplankton, periphyton, benthic invertebrates, primary productivity has been monitored. Fish diversity and availability in the river was recorded by sample collection from various sites and investigation with local people. Standard protocols (APHA, 1989, Vishwanath *et al.,* 2011) for analysis of water quality and random sampling for analysis of fish sample were carried out during the study period.

RESULTS AND DISCUSSION

1. Hydrology of Dirang chu: The river Dirang originates in the upper Himalayan ranges at an elevation of about 4600m bordering Bhutan near Bangajang and Luguthang extending from 92° 18" to 92°52" E longitudes and 27°18" to 27°22" N longitudes. Dirang Chu ('Chu' means 'River' in local dialect) which runs parallel to the main highway all the way up to and beyond Dirang. The old name of Dirang chu was "Mewa ri" and is also known as "Gong ri" (big water body). The topography of the basin is hilly with steep slopes in upper regions and moderately plain areas in lower regions. The river in its upper reaches generally flows in north-south direction, taking almost straight course. Dirang river in its total route confluences with many major and minor tributaries and carries all of the discharge to Kameng river system, a right bank tributary of river Brahmaputra. Most of the tributaries, rivulets are known by the name of the towns they come across. The catchment area extends across international border and some of the tributaries have origin in Bhutan/ Tibet. About 20% of the total catchment area in the upper reaches remains snow bound throughout the year and keeps contributing to the river flow during the lean months in the form of glacial melt. The remaining catchment area of about 80% is rain fed. The valley receives varying amounts of rainfall, ranging from a minimum of 1000 mm in the upper reaches to about 5000 mm in the extreme foothills annually and the average rainfall is fairly high. The catchment is covered by thick forest, which gives the advantage of maximum runoff of the rainwater into the river and also ensures minimum inflow of silt. The area has a number of species of flora and fauna and abundant aquatic life in the river. The hilly regions are low in fertility due to rock out-crops, boulders and gravels. There are no major sources of organic pollution loading in the Dirang valley. The river valley has low population density with low cropping intensity. The low cropping intensity coupled with low agro-chemical dosing also means that the pollution load due to agro-chemicals is quite low. The absence of industries implies that there is no pollution load from this source as well.

2. Meteorology and climate: The Dirang valley falls under Alpine/Mountain climatic region as per climatic classification of India, which is an indicator of low temperature conditions. The climatic conditions in West Kameng vary greatly with change in altitudes. Four seasons are distinctly observed in the valley (Borthakur, 1986) viz., (i) Pre Monsoon (March-May): Temperature generally ranges between 7-22°C. Humidity varies from 81-87% (ii) Monsoon (June- September): the area receives maximum rainfall under the influence of southwest monsoons during this season. The average annual rainfall in the region is 997 mm (1998-2006). The temperature generally ranges from 10-24°C and humidity varies from 90-84%, (iii) Post Monsoon (October-November): in this season, there are occasional showers. (IV) Winter Season (December to February): The minimum and maximum temperature in this season varies from 1° C and 14°C. The wind direction is southward to north in the monsoon and northward to south in the winter season. No snowfall data is available in the valley.

3. Aquatic ecology and water quality: 3.1: *Temperature* - The climate of the Dirang valley varies from severe cold to mild depending upon the altitude of the area and extent of exposure to sun. The adjoining valleys are warm during summer and experience severe cold during winter due to heavy snow fall in high

altitudes. The temperature in upper reaches in winter falls below 0ºC. The normal annual temperature for the valley is less than 20º C. The temperature data has been recorded in Table-1.

3.2: *Dissolved oxygen* - Dissolved oxygen concentrations increase wherever the water flow becomes turbulent, such as in a riffle area, waterfall, or a dam. Oxygen concentrations are much higher in air, which is about 21 percent oxygen, than in water, which is a tiny fraction of 1 percent oxygen. Where the air and water meet, this tremendous difference in concentration causes oxygen molecules in the air to dissolve into the water until saturation is reached. More oxygen dissolves into water when turbulence caused by rocky bottoms or steep gradients brings more water into contact with the surface. The oxygen content in the Dirang river was found to be above the optimum requirement of the fishes. The dissolve oxygen has been recorded in Table-1.

Table 1: Estimation of water quality parameters of Dirang river in different seasons

Water quality parameters	Unit	Pre-monsoon (March-May)		Monsoon (June-September)		Post-monsoon (October-November)		Winter (December-February)	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
pH	-	7.2-7.4	7.1-7.3	7.2-7.5	7.2-7.5	7.3-7.6	7.2-7.5	7.5-7.6	7.4-7.8
Temp.	^{o}C	7.9-16.7	6.7-14.0	7.2-19.3	8.2-18.8	6.8-16.4	6.3-15.0	6.1-7.2	6.2-7.2
Dissolved Oxygen	mg/l	8.5-8.7	8.9-8.8	8.4-9.0	8.4-10.3	8.5-11.0	8.3-10.8	8.6-11.2	8.4-11.0
Electrical conduc-tivity (EC)	µS/cm	70-115	75-112	75-78	74-112	67-110	66-122	78-120	77-115
Total Dissolved Solids (TDS)	mg/l	48-51	45-48	44-50	45-52	45-51	47-53	50-52	48-51
Alkalinity	mg/l	34-44	26-35	22-34	23-36	47-52	43-55	52-57	47-52
Hardness	mg/l	35-37	33-37	37-40	34-41	32-42	37-43	40-47	39-44
Calcium hardness	mg/l	15.1-15.3	14.1-15.0	15.0-15.2	15.1-15.3	15.2-15.4	15.0-15.3	15.1-15.4	15.1-15.3
Magnesium hardness	mg/l	3.0-3.1	3.0-3.1	3.1-3.3	3.0-3.2	3.0-3.2	3.0-3.3	3.1-3.3	3.0-3.1
Fluorides	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrate	mg/l	4.9-5.8	4.6-5.5	4.2-6.0	4.1-5.8	4.3-6.1	4.2-6.2	5.6-6.5	4.2-5.5
Phosphate	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
BOD	mg/l	1.4-1.5	1.2-1.4	1.1-1.2	1.2-1.6	1.2-1.4	1.2-2.0	1.5-2.1	1.2-1.8
COD	mg/l	2.8-3.1	2.2-2.8	2.4-3.2	2.3-3.5	2.5-3.4	2.2-3.5	3.0-3.9	2.2-2.8
Faecal coliform	MPN/ 100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Total coliform	MPN/ 100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

3.3: *Other water quality parameters* - River water at all the sites investigated was relatively alkaline. The pH values ranged from 7.2 to 7.6. The total hardness in various water samples ranged from 32-40 mg/l, 40-47 mg/l and 34.1-39.5 mg/l in post-monsoon, winter and summer seasons respectively. The low calcium and magnesium levels are responsible for soft nature of water. The carbonate hardness (for water with alkalinity level as observed in the study area) is equal to the alkalinity level. The non-carbonate hardness accounts for the balance hardness. Normally non-carbonate hardness can be removed by boiling. However, hardness levels in the area do not warrant any treatment. The low EC and TDS values indicate the lower concentration of cations and anions. This is also reflected by the fact that the concentration of most of the cations and anions are well within the permissible limit. The fluorides level was lower than the permissible limit (1 mg/l) for drinking purposes. The BOD and COD values are well within the permissible limit, which indicates the absence of organic pollution loading. This is mainly due to the low population density and absence of industries in the area. The marginal quantity of pollution load which enters river Dirang gets diluted. In fact, even for the minimum flow, there is more than adequate water available for dilution. The total coliform and faecal coliform are also low. The concentration of various heavy metals was below the permissible limit specified for domestic use. Thus, it can be concluded that water quality was observed to be quite good for

survival and maintenance of fish species (Table 1), as various parameters are well below the permissible limit specified for meeting domestic requirements, irrigation, agriculture, fisheries and livestock.

3.4: *Phytoplankton* - Phytoplankton is the autotrophic component of the plankton community and plays an important role in the primary production process in the stream ecosystems. They serve as a base of the aquatic food web, providing essential ecological function for all aquatic life. In terms of numbers, the important groups of phytoplankton comprise of diatoms, dinoflagellates, cyanobacteria, and other groups of unicellular algae. The species composition of two conditions viz. lake conditions and river conditions will be different. Density and diversity of phytoplankton in the river water was studied by collecting samples from various sampling locations. A total of 15 numbers of phytoplankton were found viz. Myxophyceae-3, Chlorophyceae-5, and Bacillariophyceae-7. Phytoplankton density ranged from 3-40 individuals/l at various sampling sites, which was dominated by the members of Bacillariophyceae.

3.5: *Zooplankton* - Density and diversity of phytoplankton in the river water was studied by collecting the samples from various sites of Dirang Chu. The density and diversity of zooplankton species was highest in all the sites in April and it showed decreasing trend in the months of May, June, July, August and September. Zooplankton community in Dirang river was dominated by members of *Rotiferans* and *Cladocerans* which mostly feed on fish waste, dead bacteria, algae and small particles of food suspended in water generated from falling leaf litter from the riparian forest areas. The dominant genera were *Difflugia*, *Colurella*, *Testudinella*, *Keratella* and *Polyarthra*, although their dominance varied across sites and seasons in the river. Zooplankton density ranged from 3-27 individuals/l at various sampling sites monitored for the study. It indicates the poor diversity of zooplankton in the Dirang river.

3.6 : *Periphyton* - The periphytic algal components were sampled and analyzed in the selected sites. Samples of periphytic algae were collected by scraping 1 cm^2 area of the substratum on which they were growing. The scraped algae were then put in a small container and brought to the laboratory for identification. Density of the periphytic algae was expressed in terms of cm^2. Periphyton communities were prominent in the months of April, May and June in the shallow, rocky and gravelly bottoms in all the sites of Dirang Chu. However, their population became insignificant in the months of July, August and September, which could be attributed to frequent flooding, and turbidity of the river water during these months. The common periphyton genera found in the samling sites were *Nitzchia, Cymbella cistula, Hormidium, Cosmerium, Spirotaena, Gloeocapsa, Nitzchia* and *Chlorella.* Overall, 8 taxa of periphytic algae were recorded from all the sites in the Dirang river. Periphyton density ranged from 60-120 individuals/cm^2 at various sampling sites monitored for the study.

3.7: *Benthic invertebrates* - In the present study, an enumeration of benthic invertebrates was done in order to know their composition, density and diversity in different reaches of the river. Dirang river showed a high diversity of benthic invertebrates with overall 29 taxa of invertebrates belonging to 8 orders were recorded from all the sampling sites. Members of Ephemeroptera, Trichoptera, Plecoptera and Diptera dominated the invertebrate group. Other orders included Coleoptera, Hemiptera, Megaloptera and Odonata. The families of macroinvertebrates included Baetidae, Chironomidae, Corixidae, Corydalidae, Dytiscidae, Ecdyonuridae, Elmidae, Ephemerellidae, Gomphidae, Gyrinidae, Heptageniidae, Hydropsychidae, Leptoceridae, Leptophlebiidae, Limoniidae, Molannidae, Nemouridae, Peltoperlidae, Perlidae, Perlodideae, Philopotamidae, Polycentropidae, Psychomyiidae, Rhagionidae, Rhyacophilidae, Simulidae, Tabanidae, Taeniopterygidae and Tipulidae. The diversity and abundance of macro invertebrates was higher in the months of March, April and May while it decreased in the rainy months of July, August and September. The density and abundance of macro invertebrates in the later months decreased due to increased water flow regime, which washed off the macro invertebrates and their habitats. Benthic invertebrates density ranged from 5-61 individuals/m^2 at various sampling sites monitored for the study. Benthic invertebrates are organisms that live on the bottom of a water body (or in the sediment) and have no backbone. Their size spans 6-7 orders of magnitude and they range from microscopic (*e.g.* micro invertebrates, <10 microns) to a few tens of centimeters or more in length (*e.g.* macro invertebrates, >50 cm). Benthic invertebrates live either on the surface of bedforms (*e.g.* rock, coral or sediment - epibenthos) or within sedimentary deposits (infauna), and comprise several types of feeding groups e.g. deposit-feeders, filter feeders, grazers and predators. The abundance, diversity, biomass and species composition of benthic invertebrates can be used as indicators of changing environmental conditions.

3.8: *Primary productivity* - Phytoplankton is autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are

the diatoms, cyanobacteria, dinoflagellates and coccolithophores. Phytoplankton accounts for half of all photosynthetic activity on Earth and contribute significantly to primary production process in aquatic ecosystems. Phytoplankton primary productivity is defined as the rate of organic matter production by the growth of planktonic plants. The details of primary productivity in different sampling sites are summarized in Table 2. Gross primary production (GPP) and net primary production (NPP) show an increase in the months of April and May, and then decreases in the months of July, August and September in all the sites. Net Primary Productivity (NPP) ranged from 7.5 - 33.3 mg C/m^2/day at various sampling sites monitored for the study.

The diatom species, which were abundant in both benthic as well as planktonic forms were *Achnanthidium minutissima*, *Achnanthidium microcephala*, *Achnanthidium exilis* and *Achnanthidium linearis* followed by *Hannaea arcus*, *Synedra ulna* var. *oxyrhynchus*, and *Fragilaria construens.*

Table 2: Primary productivity of Dirang river

	Month wise estimation of primary productivity					
	April	May	June	July	August	Sept
Gross Primary Productivity (GPP)	32.5- 35.5	60.5- 61.5	25.1-28.1	12.5-15.5	15.1- 18.1	15.5-16.5
Net Primary Productivity (NPP)	24.5-27.5	32.2-33.3	14.4-18.4	7.5-9.5	9.4-12.4	11.2-13.3

4: Diversity of fish fauna*:* Bagra, *et al*. (2009) prepared a checklist of 213 species of fishes for Arunachal Pradesh of which 138 species were first hand collections from 35 rivers in the state. About 5 species are endemic to this region viz., *Amblyceps apangi*, *Amblyceps arunachalensis*, *Labeo devdevi*, *Osteacheilus neilli* and *Calisa labiosus* (CAMP, 1997) The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topography. The higher elevations have cold water forms such as *Schizothorax* spp., *Glyptothorax* spp. etc. The foot hills and mid-elevations comprises of Mahseers such as *Acrossocheilus hexagonolepis*, *Tor tor*, *Tor putitora* which are economically important. Other species include *Labeo dero*, *Labeo pangusia*, *Clarius spp*., *Wallago attu*, *Aborichthys aor*, *Pabda spp*., *Notopterus notopterus*, *Belone cancila* etc. The state also has a large number of ornamental fishes such as: Barbs and minnows (*G. chapra*, *A. mola*, *P. ticto*, *A. morar*, *S. bacaila*), Cat fishes (*Ailia coila*, *B. tengana*, *H. hara*, *G. horal*, *M. vittatus*, *M. montanus*), Eels (*M. aculeatus*, *M. armatus*, *P. indica*), Glass fish (*C. baculis*, *C. nama*, *C. ranga*), Gourami (*C. fasciata*, *C. labiosus*), Loaches (*A. elongatus*, *A. kempi*, *N. devdevi*, *B. dario*, *B. rostrata*), Needle fish (*X. cancila*), Perches (*B. badis*, *N. nandus*), Snakeheads (*C. marulius*, *C. striatus*, *C. orientalis*), Puffer fish (*T. cutcutia*), Knife fish (*N. notopterus*).

4.1: *Fisheries of West Kameng* - The district West Kameng is one of the largest in terms of geographical, topography as well as river drainage. It harbors many rivers, streams and streamlets, which supports diverse fish species of which many are endemic to the region. Fish species like the *Botia dario*, *Barilius bendelisis*, *B. bola*, *Punitus chola*, *Tor putitora*, *Danio spp*., *Garra spp*., *Gotyla gotyla*, *Anguilla* are found in the rivers of West Kameng district. Several spawning grounds of the coldwater species were also identified in the river valley.

4.2: *Assessment of fish diversity* - The commercial fisheries are non-existent in the river Dirang. Fishing by individuals is only practiced during the lean season in the river valley by the anglers and the traditional fishers. The inaccessible terrain is also one of the reasons that the fishermen are not able to operate their fishnets very effectively. Random sampling in selected areas of the river was carried out using a cast net, hook and line at morning and evening hours. The sampled fishes were identified which belong to 8 families i.e. Cyprinidae, Salmonidae, Bolitoridae, Cobitidae, Siluridae, Amblycipitidae, Sisoridae and Bagridae (Menon, 1999; Vishwanath *et al.,* 2011). Overall, the cyprinid fishes dominated in the Dirang river.

Snow trout comprises *Schizothorax richardsonii* and *Schizothorax progastus* and are endemic to Himalaya. These fish are herbivores, column feeders and feed on benthic algae with powerful muscular streamlined body. Snow trout account for major and important part of the capture fishery in the region. *Salmo trutta fario* (Brown trout) is exotic fish species, introduced in certain stretches of Dirang chu from a hatchery established by State Fishery Department at Nuranang and Shergaon. Fry of trout are directly stocked in Dirang Chu, however, a self-sustainable population of brown trout could not be established in the river so far. *Botia berdmorei* (Blyth's loach) and *B. rostrata* (Gangetic loach) are bottom dweller fish and are

carnivorous. They get shelter among the pebbles and shingles in shallow waters. They are not of any commercial fishery interest due to their small size but are considered as aquarium fish. *Botia berdmorei* is designated as 'endangered' species. Generally, these species do not come in the catch, particularly by the cast net and hooks.

Catfish group comprises *Mystus vittatus* and *Amblyceps sp*, which belong to families Bagridae and Amblycipitidae respectively. *Mystus vittatus* prefers to inhabit muddy bottom, therefore, very rarely comes in the catch. *Amblyceps sp* is a bentho-pelagic freshwater species, which clings to the stones/pebbles in the rapid water current. Both species are not of any commercial fishery interest. Sisorid group of fish comprises *Erethistoides montana*, *Euchiloglanis hodgarti*, *Exostoma berdmorei*, *Gagata cenia* and *Pseudechneis sulcatus*. None of these species is of commercial interest and all are rheophilic and bottom feeders. *Erethistoides montana* has been categorized as 'critically endangered' fish, whereas *Euchiloglanis hodgarti* and *Pseudecheneis sulcatus* are designated as 'vulnerable' (IUCN, 2014).

Average catch per unit effort (CPUE) was recorded to be 0.03 kg/per day and 0.05 kg/day in winter and pre-monsoon seasons, respectively. Hook and line methods, cast nets were mostly used to land the fish. Bamboo woven traps and gill nets were also seen in certain stretches of the river. The capture fishery depends mainly on the snow trout (*Schizothorax richardsonii* and *Schizothorax progastus*). The low CPUE and scanty population indicated by the low density of fish in the upper reaches which may be due to passage of river through deep and narrow gorges, and presence of cold glacier and snow-melt water, which is not conducive for much fish diversity at these altitudes.

5: Fisheries development plan: In Kameng drainage and its tributaries; *Schizothorax richardsonii, Botia berdmorei, Erethistoides montana, Euchiloglanis hodgarti* and *Pseudecheneis sulcatus* are threatened species, in which *E. montana* is 'critically endangered' and *B. berdmorei* is 'endangered' (Vishwanath *et al*, 2011). The proposed plan of fishery development is aimed towards conservation of indigenous species of Dirang river and its tributaries. Some of the plans are: i) Establishment of Hatchery Unit, ii) Habitat improvement, iii) Awareness among mass about the conservation of the endangered species, iv) Diversification of fish species for aquaculture practices for livelihood, iv) Promotion of eco-tourism and angling for income generation, v) Ban of usage of fish poisons and dynamites, vi) provision of fisheries manpower in furlong areas of hilly terrains.

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