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Phytoplankton diversity and abundance in upland streams of Kameng drainage, Arunachal Pradesh

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Abstract
Plankton and fish constitute a major component of freshwater environment as they play pivotal role in maintaining the biodiversity and ecosystem functions. The present study was carried out in three snow-fed tributaries viz, River Dirang *chu* (27.3537 N, 92.2506 E), River Sangti (27.3517 N, 92.2681 E) and River Tenga (27.2186 N, 92.43 E) of Kameng drainage, Arunachal Pradesh in the Eastern Himalayas. The key physicochemical parameters *viz*., temperature, pH, dissolved oxygen, alkalinity, hardness etc, recorded in tributaries range between 11.42±0.04 to 14.25±0.06^{O}C; 7.32±0.02 to 7.9 ± 0.03; 8.06 ± 0.05 to 8.31 ± 0.05 ppm, 33 ± 2.31 to 17.33 ± 2.31 mg/l; 26.66±1.15 to 15.33±1.15 mg/l respectively. A total of 32 phytoplankton genera belonging to 10 classes, 23 orders and 29 families were identified from the Dirang chu, Sangti and Tenga tributaries of Kameng drainage. The abundant genera identified from river sangti were *Stigeoclonium* (50%), *Pinnularia* (20%), *Navicula* (15%) whereas *Stigeoclonium* (30%), *Fragilaria* (30%) and *Lyngbya* (10%) dominated at river Sangti and in river Tenga the abundant ones were *Pinnularia* (30%), *Acanthidium* (20%) and *Synedra* (9%).The dominant classes identified from the drainage were Bacillariophyceae, Chlorophyceae, Cyanophyceae and Fragilariophyceae. The abundance of diverse plankton groups along with a favorable range of most of the essential hydrological characteristics indicated a good health of the water body and an environment conducive for thriving of phytoplankton.

Keywords: Kameng drainage, phytoplankton, physicochemical parameters, Eastern Himalayas

1. Introduction
Rivers are important systems of biodiversity and are among the most productive ecosystems on the earth because of the favourable conditions that support number of flora and fauna. River ecosystem is one of the natural resource which comes into the service of mankind in many parts of the world. They play a vital role in the productivity as they are beset with varieties of flora and fauna including plankton.Phytoplankton are the primary producers of water bodies, these are the main source of food directly or indirectly for various animal groups. The productivity of any aquatic water body depends on the amount of plankton present in the said water body [1]. Aquatic ecosystem harbours a variety of communities, which constitute the characteristics and functioning at the ecosystem in term of maintaining production and food chain.In the aquatic ecosystem, phytoplanktons are foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell and fin-fish [2]. According to Ekwu and Sikoki, 2006 [3] the phytoplankton of an aquatic ecosystem is central to its normal functioning.The plankton population observation may be used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies [4]. The use of density and diversity of phytoplankton and their association as biological indicators in the assessment of water quality or trophic status has been made by several workers [5-7]. Presently, phytoplanktons are being used increasingly by scientists to monitor the ecological quality and health of the aquatic environment. As reported by Brierley *et al*., 2007 [8], phytoplanktons are also used to measure the effectiveness of management or restoration programmes or regulatory actions in aquatic environment. The plankton community is a dynamic system that would quickly respond to changes in the physical and chemical properties of the water environment, as they represent the base-line of the food chain in the aquatic ecosystem [9]. The position they occupy in the trophic level makes them more vulnerable and highly sensitive to even a small degree of environmental changes, hence they act as indicators of water quality [10].
Kameng River is an important tributary of Brahmaputra river. The Kameng River was known as Bhareli River in the past.

It now flows as Kameng within Arunachal Pradesh and takes the name Jia Bharali in Assam part. The upper region of the entire Kameng (or Jia Bharali) catchment falls within the Himalayan range and the lower stretches flows through the alluvial plains of the Brahmaputra. Geographically, the upstream segment of the river on the north of Bhalukpongarea is known as Kameng and its downstream segment on the south of Bhalukpong takes the name Jia Bharali till its confluence with the Brahmaputra. The Kameng river basin covers an area of 11,280 Km^2 lying within 91°55'E - 93°25'E longitudes and 26°35'N - 28°0'N latitudes. The river originates from the snowfields of Kangto massif and the Gori Chen mountain ranges.The river forms the boundary between the West Kameng and the East Kameng districts in Arunachal Pradesh.

Phytoplankton dynamics have been studied extensively in lentic fresh waters (lakes and reservoirs), yet comparatively little research has focused on lotic waters (rivers). The investigations in river planktons are scanty due to practical difficulties in the survey and sampling of flowing water. Thus an attempt was made to study the phytoplankton diversity in the snow fed streams of Kameng drainage, Arunachal Pradesh.

1.1 Study area: The study was conducted in three major snow-fed tributaries viz, river Dirang *chu*, river Sangti and river Tenga of Kameng drainage in West Kameng district of Arunachal Pradesh in the Eastern Himalayas during 2016-17. The topography of the basins is hilly with steep slopes, situated at an altitude ranging from 1411-1512m asl. All these rivers in their 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. Three sampling sites, on river Dirang *chu* (27.3537N, 92.2506E), river Sangti (27.3517N, 92.2681E) and Tenga (27.2186N, 92.43E) were selected for the present study (Fig. 1).

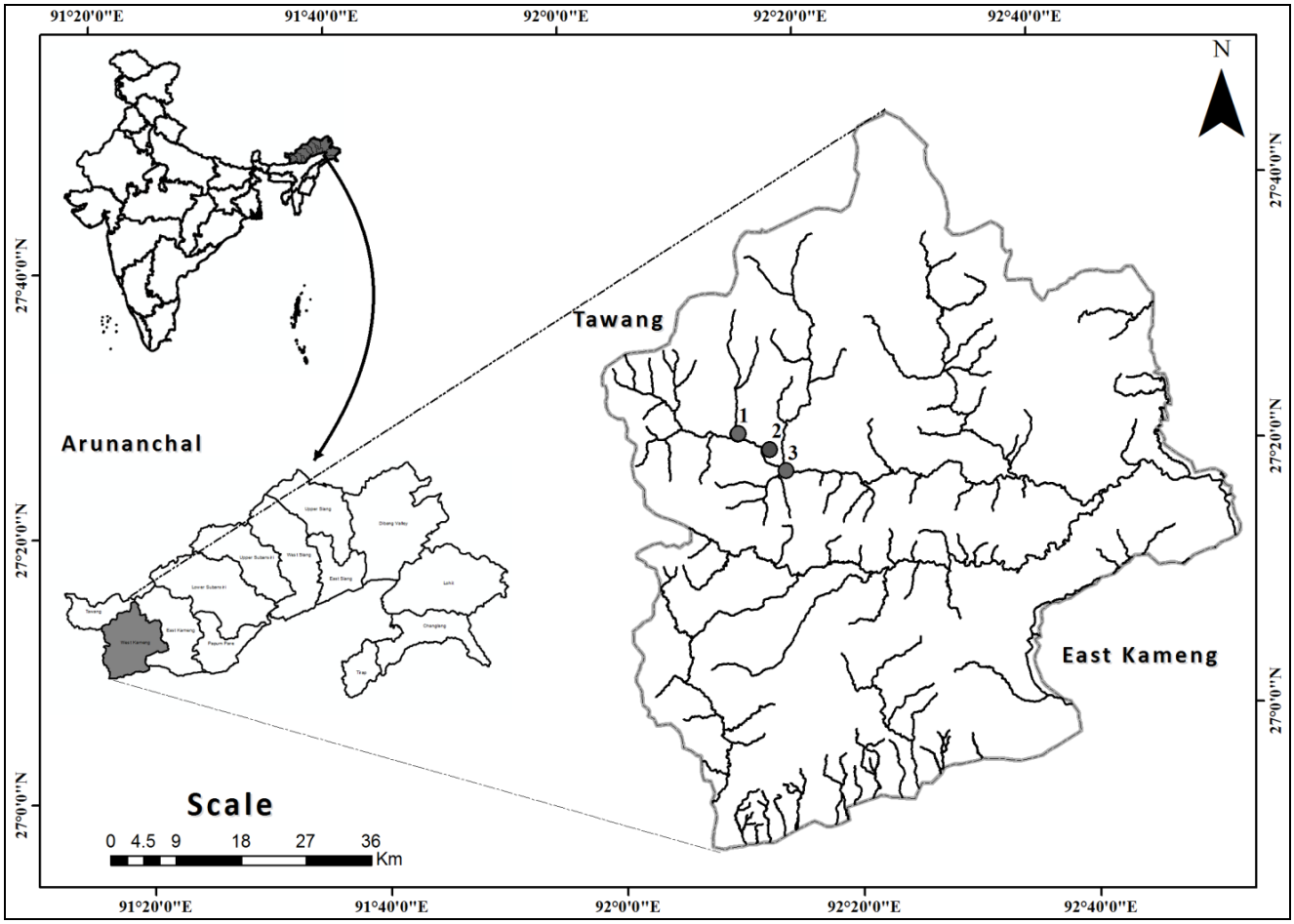

Fig 1: Location map showing the sampling points 1. River Dirang chu; 2. River Sangti; 3. River Tenga; of Kameng drainage, Arunachal Pradesh.

2. Materials and Methods

For the estimation of phytoplanktonin the river ecosystem 100 litres of water was sieved through phytoplankton net having mesh size of 69 micro meter. The filtered samples were fixed and preserved in 5% formalin with a few drops of Lugol's iodine solution [11][12].The identification of phytoplankton was made with the help of Sarode and Kamat (1984) [13],Ward and Whipple(1992) [14], Munshi *et al*., (2010) [15] and Bellinger and Sigee (2010) [16]. The physico-chemical variables of water in each sampling sites were analyzed using electronic digital multiprobe (Hanna model HI 9828) and nutrient variables were analyzed by standard methods outlined by Merck Spectroquant Multy (SN 072414) kits. Turbidity of water was analyzed by Turbidity meter (HACH-2100Q).

3. Results and Discussion

3.1 Physico chemical characteristics of the tributaries of kameng drainage.

The physico chemical and nutrient variables of water analyzed in each sampling stations is as presented in (Table 1)

and has direct and indirect effects on nearly all aspects of stream ecology. Water temperature is of enormous significance as it regulates various abiotic characteristics and biotic activities of an aquatic ecosystem. In the present study water temperature fluctuated between 11.46 to 14.80 ^{0}C across the sampling sites. Lower water temperature was due to glacial origin of the rivers and also because of cold low ambient temperature and shorter photoperiods. Jana (1973) & Chari (1980) [17, 18] stated that temperature is a critical factor for seasonal periodicity of phytoplankton. Morover, the temperature in the snow-fed rivers remains within 20º C and falls below 0 ºC in winter.

Dissolved oxygen (DO) is the sole source of oxygen for all the aerobic aquatic life and hence it is considered as an important measure of purity for all waters. DO reflect the water quality status and physical and biological processes in waters and show the metabolic balance of a river system. DO is an important water quality parameter in assessing water pollution [19]. In the present investigation, DO recorded at different sampling sites varied between 8.06 to 8.13 ppm. The higher DO level can be due to lower temperature and turbulent flow of rivers. Morover, at such temperature processes which consume oxygen such as metabolic activity of aquatic biota and deocmposition of organic matter by bacteira and other microbes gets slowed down [20]. As cold water can hold more oxygen than warm water, certain species of aquatic invertebrates and fish with high oxygen demands (snow trout) are found abundantly in these waters. Total dissolved solids (TDS) test measures the amount of particles that are dissolved in water. The WHO standard is 1000 mg/l. TDS in excessive amounts may be unsuitable for aquatic life and crop irrigation. The total dissolved solids concentration varied between 8 to 62 NTU between the sampling sites. The low TDS values indicate the concentration of cations and anions are well within the permissible limit. The low calcium and magnesium levels are responsible for soft nature of water in river Dirang *chu* whereas the values are little higher in river Sangti and Tenga which may be attributed due to human habitation. pH is considered as an indicator of overall productivity that causes habitat diversity [21]. pH values recorded range between 7.30 to 7.90 at different sampling stations. Low pH < 5.0 can severely reduce aquatic species diversity [22]. However, pH range was reasonably good at all stations thereby suitable for phytoplanktonic population. The recorded pH values were good enough for phyto-planktonic growth at all the sampling stations. Turbidity is the measure of degree to which the water loses its transparency due to the presence of suspended particles. The turbidity values recorded ranged between.31 to.48 NTU at all sampling stations indicating water to be conducive for growth of aquatic flora especially phytoplankton. Alkalinity is a measure of weak acid present in water and of the cations balanced against them [23].It ranged between 16 to 52 mg/l at different sampling stations. The total hardness is determined by cations that form insoluble compounds with soap and it correlated with calcium, alkalinity, and pH [24] and it was recorded between 14.0 to 64.0 mg/l at different sampling stations. Phosphate and nitrate are considered to be the critical limiting nutrients, causing eutrophication of fresh water systems [25]. In the present study phosphate and nitrate were present in minimum possible concentration and were quite significant during the study period. All the river sites being snow fed remained clear and transparent in the study period. Most of the essential water quality parameters were within the optimum level concluding a good health of the water body and conducive for the abundance of phytoplankton.

Table 1: Physico-chemical parameters of water in rivers of West Kameng, district of Arunachal Pradesh

Parameters	Dirang chu	Sangti river	Tenga river
D.O (ppm)	8.13 ± 0.02	8.06 ± 0.05	8.31 ± 0.05
pH	7.32 ± 0.02	7.90 ± 0.03	7.33 ± 0.02
Temperature (^{O}C)	14.0 ± 0.08	11.46 ± 0.04	13.20 ± 0.06
Conductivity (µS/cm)	16.00 ± 2.00	50.0 ± 5.00	124.0 ± 11.00
TDS (ppm)	8.00 ± 1.00	25.00 ± 4.00	62.00 ± 6.00
Turbidity (NTU)	0.48 ± 0.11	0.31 ± 0.01	0.37 ± 0.02
Alkalinity (mg/L)	16.0 ± 0.01	28.0 ± 0.02	52.0 ± 2.00
Hardness (mg/L)	14.00 ± 1.15	26.00 ± 2.00	64.00 ± 4.30
Phosphate (mg/L)	0.14 ± 0.01	0.36 ± 0.13	0.90 ± 0.15
Nitrate (mg/L)	4.00 ± 0.42	4.80 ± 0.31	5.80 ± 0.23

3.2 Phytoplankton communities of the tributaries of kameng drainage.

A total of 32 phytoplankton genera belonging to 10 classes, 23 orders and 29 families were identified from the dirang chu, sangti and tenga tributaries of Kameng drainage during the study period (Table 2). Bacillariophyceae, Chlorophyceae, Cyanophyceae and Fragilariophyceae were important classes in order of abundance and dominance. The 12 genera of Bacillariophyceae was the largest group of phytoplankton followed by 5 genera of Chlorophyceae and 4 genera each of Cyanophyceae and Fragilariophyceae. The other classes to follow were Trebouxiophyceae represented by 2 genera and Coscinodiscophyceae, Euglenophyceae, Synurophyceae, Zygnematophyceae, Ulvophyceae represented by one genera each (Fig 2). Maximum number of genera (27) were identified from River Tenga belonging to 8 classes, 18 orders and 23 families (Fig 3) while as least numbers were identified from River Sangti consisiting of 14 genera belonging to 3 classes, 10 orders and 12 families (Fig. 4). The river dirang chu has intermediate numbers wherin 19 genera belonging to 8 classes, 14 orders and 17 families were identified (Fig. 5). The most dominant phytoplankton identified from river dirang chu comprised of *Stigeoclonium* (50%), *Pinnularia* (20%), and *Navicula* (15%) and in river sangti the dominant ones identified were *Pinnularia* (40%), *Achnanthidium* (20%), and *Synedra* (10%). In river tenga *Stigeoclonium* (30%), *Fragillaria* (20%), and *Lyngbya* (9%), were the dominant genera identified (Fig. 6). Eight (8) genera including *Achnanthidium*, *Cocconies*, *Cymbella*, *Eunotia*, *Fragilaria*, *Navicula*, *Synedra*, and *Tabellaria* were common to each tributary. While as genera like *Pinnularia*,*Nitzschia*, *Gomphonema*, *Surirella*, *Diatoma*, *Dictyosphaerium* were common to river sangti and river tenga and the genera such as *Oedogonium*, *Stigeoclonium*, *Lyngbya*, *Oscillatoria*, *Chlorella* were common to river dirang chu and river tenga. Genera such as *Amphipleura*, *Craticula*, *Cymatopleura*,

Chlamydomonas, Aulacoseira, Microcystis, Trachelomonas were present in river tenga only and the genera like *Microspora*, *Mougeotia* and *Desmidium* were unique to river dirang chu only.

The abundance of phytoplankton and zooplankton in the fresh water bodies is greatly regulated by the physico-chemical factors [26]. Variation in temperature, light availability, nutrients, and discharge influence seasonal variation in phytoplankton abundance [27-30]. In terms of abundance Bacillariophyceae was the most dominant class followed by Chlorophyceae, Cyanophyceae, Fragillariophyceae and so on which is the general trend observed in lotic ecosystems [31]. It further adds weightage to the fact that diatoms constitute the major proportion of phytoplanktonic density in rivers and streams **[32].**The dominance of bacillariophyceae may be attributed to its ability to thrive well in cold water [33] and on the availablity of silicates which are used in the frustule formation by the diatoms **[34, 35]** and also being favoured by low temperature and high light penetration [36]. Nautiyal (1984) [37] reported that the diatoms account for more than 80% of the potamo-phytoplankton in Himalayan streams and rivers and Lee (1999) [38] reported that the diatoms contributed the major portion of bio-volume in the Snake River. Our results are in corroboration with the findings of Talling and Rzoska (1967) [39], Bisma *et al*. (2014) [40] and Malik *et al*., (2018) [41] who reported diatoms to be the major phytoplanktonic group in blue nile, river Jhelum of Kashmir Himalays and river Bhagirithi of Garhwal Himalayas respectively.

Phytoplanktons are sensitive to velocity and turbulence of flow in the streams, thus inhibiting the development of new plankton and suppress any existing organisms discharged from associated lentic waters. Thus agitated water of rithron in the kameng drainage support little plankton diveristy in river siang as compared to river dirang chu and river tenga. This is probably due to the fast turbulent flow in the former. Similar observations have been made by Welcomme (1985) [42] and Archana sharma *et al.* (2007) [43].

Genera like *Cosmarium, Pediastrum, Scenedesmus, Tetradon, Selenastrum* etc areknown to be abundant and dominanting in eutrophic waters [44]. None of the above genera was collected and identified from the stretches of the sampled tributaries of kameng drainage under investigation. It can be thus said that there is no or minimal pollution at the sampled strectches of Kameng drainage.

4. Conclusion

The upland and snow-fed rivers of Kameng drainage resembles typical V-shaped valley of Himalayan terrain surrounded by denudation hills and cultivated terraces. These river valleys are low in fertility due to rock out-crops, boulders and gravels. The results obtained in the present study indicated that a diverse phytoplanktonic population is present within the tributaries of kameng drainage consisitng of 32 genera belonging to 10 classes, 23 orders and 29 families in the following order of dominance: Bacillariophyceae > Chlorophyceae >Cyanophyceae > Fragilariophyceae etc.

Species composition in the selected tributaries of kameng drainage was similar, however with some some variations in density, numbers and abundancce. The physico chemical parameters of water estimated were all within the optiumum range for the growth of aquatic flora and fauna and thereby indicate the healthy and unpolluted nature of the drainage. Based on these findings, it can be concluded that phytoplankton diversity and abundance in the kameng drainage will contribute significantly to the sustenance of its fishery.

5. Acknowledgement

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6. Conflict of interest

The authors declare that there is no conflict of interest

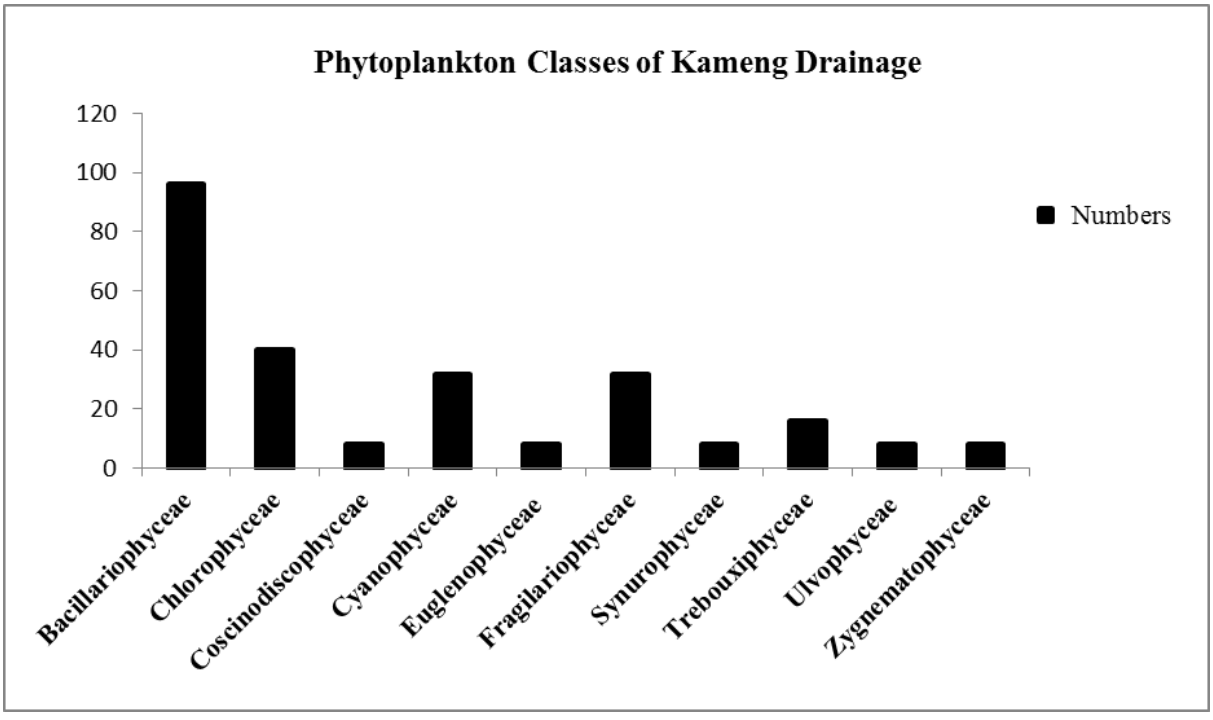


Fig 2: Class wise distribution of phytoplankton in Kameng Drainage of Arunachal Pradesh.

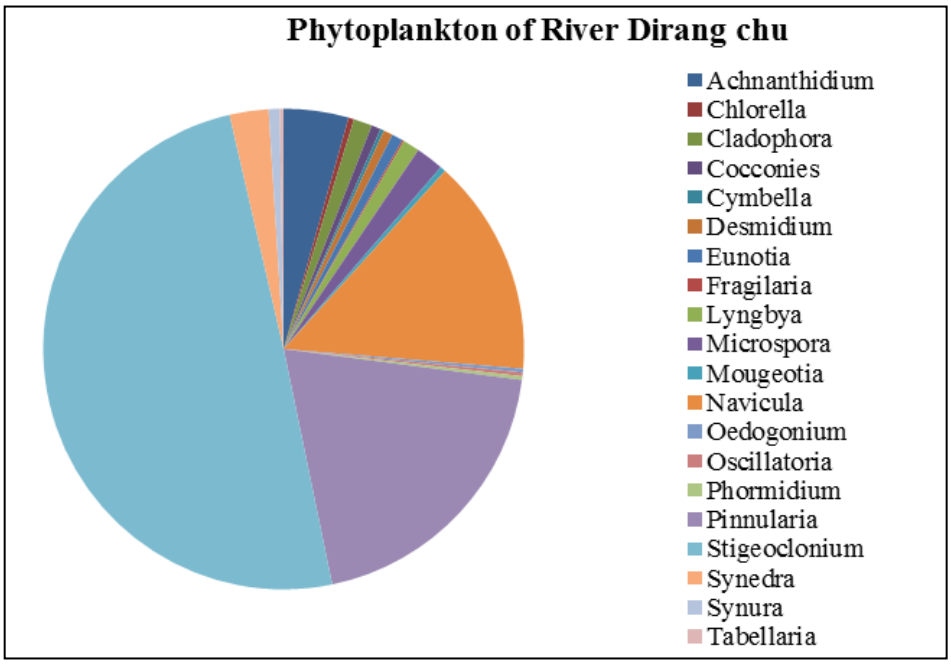


Fig 3: Phytoplankton diversity of River Dirang chu of Kameng drainage

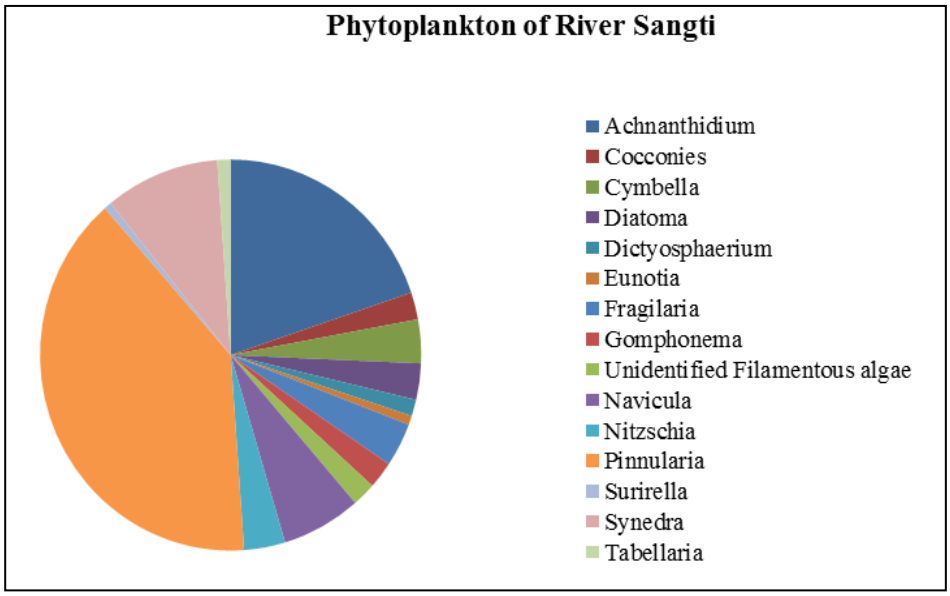


Fig 4: Phytoplankton diversity of River Sangti of Kameng drainage

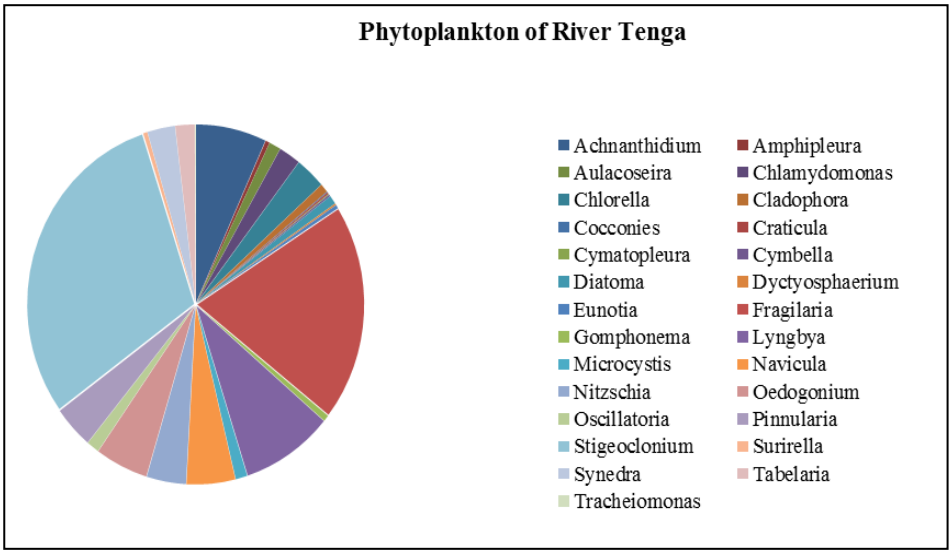
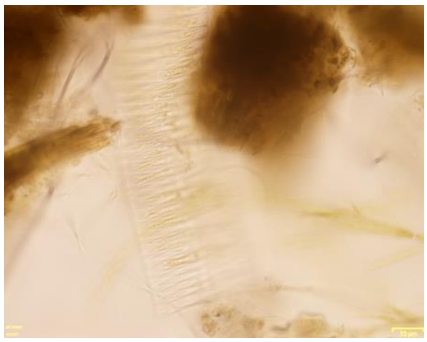


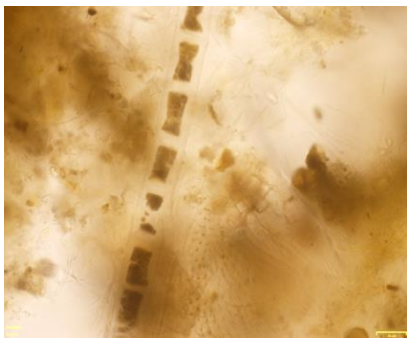
Fig 5: Phytoplankton diversity of River Tenga of Kameng drainage

Table 2: Checklist and distribution of Phytoplankton in River Dirang chu, River Sangti and River Tenga of Kameng drainage of Arunachal Pradesh.

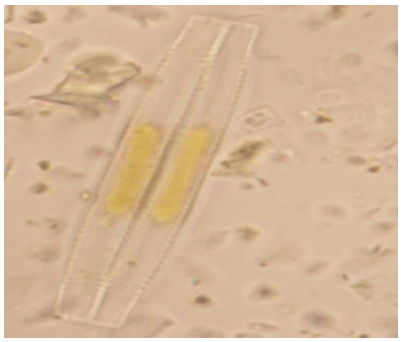
Class	Order	Family	Genera	Rivers		
				Dirang	Sangti	Tenga
Bacillariophyceae	Achnanthales	Achnanthaceae	*Achnanthidium*	+	+	+
		Cocconeidaceae	*Cocconies*	+	+	+
	Naviculales	Naviculaceae	*Navicula*	+	+	+
		Amphipleuraceae	*Amphipleura*	-	-	+
		Stauroneidaceae	*Craticula*	-	-	+
		Pinnulariaceae	*Pinnularia*	-	+	+
	Bacillariales	Surirellales	*Cymatopleura*	-	-	+
		Bacillariaceae	*Nitzschia*	-	+	+
	Cymbellales	Cymbellaceae	*Cymbella*	+	+	+
	Eunotiales	Eunotiaceae	*Eunotia*	+	+	+
	Cymbellales	Gomphonemataceae	*Gomphonema*	-	+	+
	Surirellales	Surirellaceae	*Surirella*	-	+	+
Chlorophyceae	chlamydomonadales	chlamydomonadaceae	*Chlamydomonas*	-	-	+
	Sphaeropleales	Microsporaceae	*Microspora*	+	-	-
	Zygnematales	Zygnemataceae	*Mougeotia*	+	-	-
	Oedogoniales	Oedogoniaceae	*Oedogonium*	+	-	+
	Chaetophorales	Chaetophoraceae	*Stigeoclonium*	+	-	+
Coscinodiscophyceae	Aulacoseirales	Aulacoseiraceae	*Aulacoseira*	-	-	+
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Lyngbya*	+	-	+
			Oscillatoria	+	-	+
		Phormidiaceae	*Phormidium*	+	-	-
	Chroococcales	Microcystaceae	*Microcystis*	-	-	+
Euglenophyceae	Euglenales	Euglenaceae	*Trachelomonas*	-	-	+
Fragilariophyceae	Fragilariales	Fragilariaceae	*Fragilaria*	+	+	+
			Synedra	+	+	+
			Diatoma	-	+	+
	Tabellariales	Tabellariaceae	*Tabellaria*	+	+	+
Synurophyceae	Synurales	Synuraceae	*Synura*	+	-	-
Trebouxiophyceae	Chlorellales	Chlorellaceae	*Chlorella*	+	-	+
			Dictyosphaerium	-	+	+
Ulvophyceae	Cladophorales	Cladophoraceae	*Cladophora*	+	-	+
Zygnematophyceae	Desmidiales	Desmidiaceae	*Desmidium*	+	-	-



Fragilaria

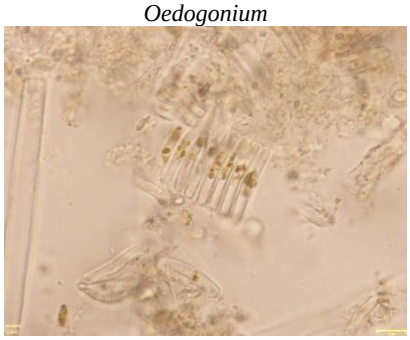


Oedogonium

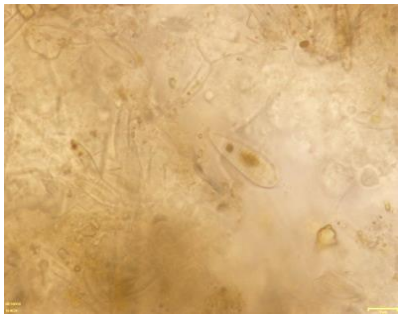


Pinnularia

Stigeoclonium



Tabellaria



Surirella

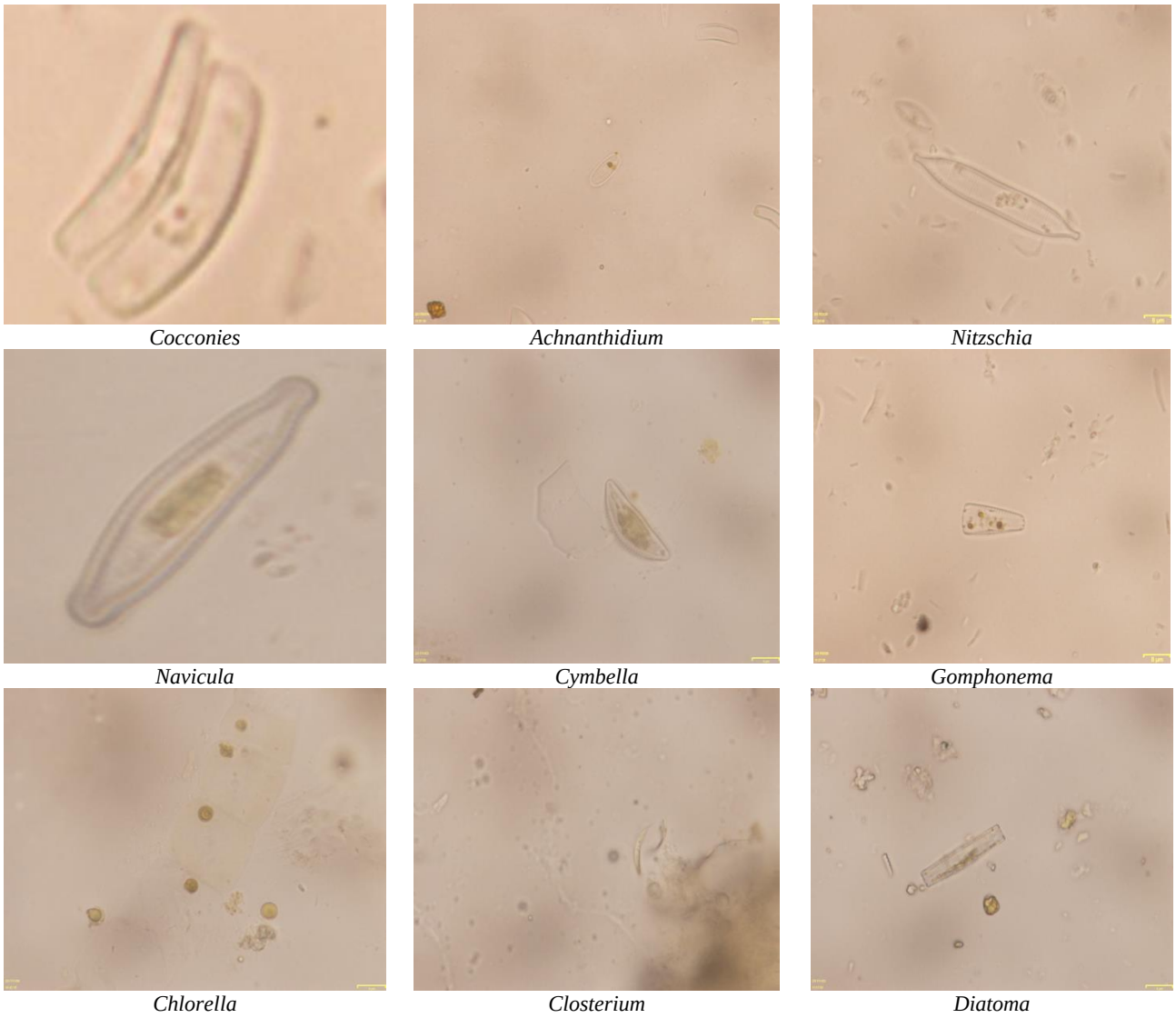


Fig 6: Some common Phytoplankton of Kameng drainage of Arunachal Pradesh

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