Indian J. Fish., 61(4) : 78-83, 2014

Observations on certain aspects of ecology of selected rivers in Nagaland State, India

S. D. GURUMAYUM[1], P. DAIMARI[2], B. S. GOSWAMI[3] AND M. CHOUDHURY[4]

[1]*Zoological Survey of India, Gopalpur-on-Sea, Ganjam - 761 002, Odisha, India*

[2]*St. John Higher Secondary Residential School, Dimapur - 797 113, Nagaland, India*

[3]*B Borooah College, Guwahati - 781 002, Assam, India*

[4]*North-eastern Regional Centre, Central Inland Fisheries Research Institute, Housefed Complex Dispur - 781 006, Guwahati, Assam, India*

e-mail : santaguru@rediffmail.com

ABSTRACT

Seasonal variations in physico-chemical parameters of water and soil, abundance and quality composition of plankton, periphyton and benthos were investigated during the period 2000-2001 in six rivers of Nagaland *viz*., Doyang, Dikhu, Tserang, Sidzu, Tezu and Zungki. Plankton, periphyton and benthos population fluctuated between 18-282 ul^{-1}, 13100-180500 u cm^{-2} and 159-508 nos. m^{-2} respectively. Dissolved oxygen, free carbondioxide, alkalinity, specific conductivity, total dissolved soilds, chloride, total hardness, Ca, Mg, Silicate, total iron, nitrate, phosphate and dissolved organic matter were found within the normal ranges of tropical hill streams. Primary productivity was found to vary within the range 500-999 mg C m^{-3} day^{-1}. The observations revealed that the rivers are mostly non-stressed in nature and are free from common problems related with anthropogenic activities.

Keywords : Nagaland, Periphyton, Physico-chemical properties, Plankton, Rivers, Soil, Water

Introduction

Rivers form an integral part of the geography of Nagaland. The proximity to the Himalayan foothills and the torrential monsoon rains contributed to the prosperity of the rivers in Nagaland. It is estimated that the state has a riverine stretch of 16,000 km. Seven rivers traverse the state, most of them are the tributaries of Brahmaputra. The Tezu is the only river that is flowing across the Naga ranges to join Chindwin drainage in Myanmar. Most of the rivers are fast flowing torrential hill streams and do not provide distinct variation. However, the state is blessed with diverse fishery resources. Substantial riverine stretches in the middle and lower altitude zones offer ample scope for fisheries. Mokokchung, Kohima and Wokha districts of the state have maximum riverine resources while Phek and Zunheboto have minimum (ISRO, 2010). The fish fauna exhibits a combination of both hill stream and plain water forms occupying diverse ecological regimes in their distributional range and contain representatives of both Assamese and Burmese element. However, rheophilic stream fauna dominates the fisheries.

A thorough knowledge of the limno-biology of rivers is important for evaluation of the fishery potential of the water bodies. Use of magnitude and dynamics of biotic communities *viz.*, plankton, periphyton and benthos to evaluate productivity of any water body has become mandatory now a days. Other than this, biotic components of aquatic ecosystems are also being used as bio-indicators of pollution of water bodies. Detailed reports are available on the hydro-biological parameters for most of the lakes, rivers and reservoirs in the country. However, only limited works have been done on various aspects of ecology and fisheries resources of the rivers in Nagaland. In the present study, a detailed investigation was undertaken to evaluate the quality and quantity of plankton, periphyton and benthos, physico-chemical parameters of water and soil as well as phytoplankton productivity in selected rivers of Nagaland.

Materials and methods

Six rivers *viz.,* Doyang, Dikhu, Tserang, Tezu, Sidzu and Zungki of Nagaland were selected for the study during the period 2000-2001. Drainage map of Nagaland showing sampling stations are indicated in Fig. 1. Doyang is the biggest and longest river of Nagaland and runs along the southern boundary of the state; it flows about 152 km within the state before it meets the river Dhansiri in Assam. The Sidzu River originates from Mao Gate and flows north-west towards Chakabama, later joining the Dzulu River and form the Doyang River. Dikhu River has a total length of about 160 km, originating from Nuroto Hill area in Zunheboto District. The river traverses towards north along the border of Mokokchung and Tuensang districts. The Tizu River forms an important drainage system in the eastern

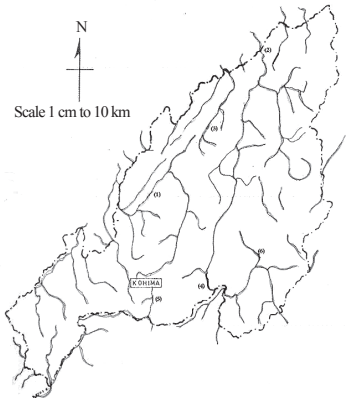

Fig. 1. Drainage map of Nagaland showing sampling sations. 1. Doyang River (Wokha); 2. Dikhu River (Naginimara); 3. Tserang River (Longthuk); 4. Tizu River (Phek); 5. Sidzu River (Sidzu); 6. Zunki River (Kiphire)

part of the state. It originates from the central part of the state and runs in the a north-east direction and flows through Zunheboto and Phek districts and empties itself in the Chindwin River of Myanmar. The Zungki is the biggest tributary of Tizu, starts from the north-eastern part of Changdong forest in the south of Teku and flows towards Kiphire and finally joins Tizu below Kiphire. Tserang is an important river which flows through the valley of Chanki. River Tserang joins Milak River and goes out of Nagaland boundary with the name Janji at Assam.

The data employed in the present study were collected during three different seasons *i.e.,* pre-monsoon (March to June), monsoon (July to October) and winter (November to February), except for Sidzu and Zunki rivers, for which due to unapproachable road condition, sampling was done only during winter. The sampling sites were Wokha, Naginimara, Longthuk, Phek, Sidzu and Kiphire respectively (Fig. 1). The parameters like temperature, dissolved oxygen, free carbon dioxide, pH, specific conductivity, total dissolved solids (TDS) and total alkalinity were analysed at the collection site iitself, whereas the other parameters like total hardness, nitrate, chloride, calcium, magnesium, phosphate, silicate, iron and dissolved organic matter of the water samples were analysed in the laboratory. Soil samples were also brought to the laboratory and analysed for texture and pH. The analytical procedures followed for all the above-mentioned parameters were as per APHA (1989). Plankton samples were collected using plankton net (nylobolt no. 25) by filtering 100 l of water and preserved in 4% formalin. Periphyton samples were collected randomly by scraping one square centimeter area from the stones/boulders, which were submerged in the riverbed. The samples thus collected were preserved in 4% formalin. Ekman dredge was used for collecting the benthic samples. A metal sieve (no. 40) was used for segregating macro-benthos, whereas a piece of organdie cloth (0.33 mm mesh size) was used to sieve the smaller organisms. Samples were preserved in 10% formalin for further study. Plankton, periphyton and benthic forms were enumerated following standard methods and identified following Edmondson (1959), Needham and Needham (1966), Desikachary (1959), Iyengar and Desikachary (1981), Philipose (1967) and Ramanathan (1964). Rate of primary production was studied by using dark and light bottle method (Garder and Gran, 1927).

Results and discussion

The results of physico-chemical analysis of water from the rivers of Nagaland are shown in Table 1. The study revealed that the rivers in Nagaland were rich in dissolved oxygen (7.6-9.0 mg l^{-1}) and low in carbon dioxide (0-5.7 mg l^{-1}) except the Tserang where carbon dioxide was higher than that recorded in other rivers (3.7-7.6 mg l^{-1}). Carbon dioxide was totally absent in the Sidzu and Zunki rivers during the period of study. High dissolved oxygen and low carbon dioxide is a well-known characteristic feature of hill streams (Nath, 2001; Pathak, 2001; Singh, 2010). Similar observations were also recorded from the hill streams of Meghalaya (Gurumayum *et al.,* 2002) and Manipur (Singh *et al*., 2010). Water temperature varied between (12.8-24.5 ^{o}C), which lies near the favourable range for cold-water fishes (0-20 ^{o}C). pH values were within a narrow range of 7.4-7.6. In the present study, mostly bicarbonate alkalinity was observed and total alkalinity fluctuated with in the low range of 37.6-86.5 mg l^{-1}. Such lower alkalinity values were also reported from the rivers of Meghalaya by Gurumayum *et al.* (2002) whereas Singh *et al.* (2010) observed much higher values from the rivers of Manipur. Chloride content of the rivers varied from 24-38.3 mg l^{-1}, the observation agrees with that of Singh (2010) from the rivers of Manipur. A much lower value from Moirang River was reported by Laishram Kosygin (2007) from Manipur itself. Total iron content of the rivers is within the range of 0.17-0.60 mg l^{-1}, which corroborate with the findings of Gurumayum *et al*. (2002) from the rivers of Meghalaya. Ellis (1937) opined that presence of more than 2 mg l^{-1} of iron usually points to conditions unfavorable for fishes and in the present study, all values were within the favorable range. Total dissolved solids (47.5-150 mg l^{-1}) and specific conductivity (93.6-321μ mhos cm^{-2}) values were low and far less than recommended value given by WHO (1995) (500 mg l^{-1} and 750 μ mhos cm^{-2}). Maximum value for both TDS and specific conductivity was observed in Sidzu River during winter. Dissolved organic matter values varied between 1.2-2.9 mg l^{-1}. Gurumayum *et al.* (2001) also reported similar range from Subansiri River of Arunachal Pradesh. However, higher value of DOM was reported from Mahanadi River (Pathak *et al*., 2001a) and tributaries of river Barhmaputra (Pathak *et al*., 2001b). They opined that when the rivers flow through deep forests, falling of tree leaves on the river water is expected to enrich carbon content of the rivers.

Total hardness is the parameter of water quality which is generally used to describe the effect of dissolved minerals (mostly calcium, Ca and magnesium, Mg), determining the suitability of water for domestic, industrial and drinking purposes and these are mainly attributed to presence of bicarbonates, sulphates, chlorides and nitrates of Ca and Mg (Taylor, 1949).Water with hardness values up to 60 mg l^{-1} are referred to as "soft", those having 120-180 mg l^{-1} are referred to as "hard". Total hardness varied with in a wide range of 13-175 mg l^{-1}. Maximum fluctuation was observed in Doyang River (13- 135 mg l^{-1}). Dikhu, Tserang and Tezu can be categorised

Table 1. Range of physico-chemical parameters of water from the rivers of Nagaland

Parameters	Name of the river					
	Doyang	Dikhu	Tserang	Tezu	Sidzu	Zunki
Air temperature (^{0}C)	18.3-26.5	20.7-24	17.3-22.5	19.3 -25	20	19.3
Water temperature (^{0}C)	12.8 -22.5	16.6 -21	16.2 -24.5	14.3 -21	18	14.3
pH	7.6	7.4	7.6	7.4 -7.6	7.8	7.4
CO_2 (mg l^{-1})	0-4.7	4.2 -5.7	3.7 -7.6	0 -5.7	0	0
Dissolved oxygen (D O) (mg l^{-1})	7.6 -8.8	8.2 -9.0	7.6 -8.4	8.4 -8.6	8.6	8.6
Transparency (cm)	BV -7.5	BV -28.5	BV	BV	12.5	BV
Carbonate alkalinity (mg l^{-1})	0-9.4	0	0	0 -3.2	7.5	3.2
Bicarbonate alkalanity (mg l^{-1})	37.6 -79.4	37.6-48.9	67.7 -77.1	63.9 -79.4	63.9	79.4
Total alkalinity (mg l^{-1})	37.6-86.5	37.6 -48.9	67.7 -77.1	63.9-82.6	71.4	82.6
Specific conductivity (µ Mhos cm^{-2})	98.8 -195.7	93.6 -133.4	128.2 -167	145.9 -160.8	321.0	145.9
TDS (mg l^{-1})	49.2-99.2	47.5 -67.5	64.3-81.1	73.9 -79.1	150.0	73.9
Chloride (mg l^{-1})	28.7-38.3	24 -33.5	28. -33.5	28.7-38.3	38.3	28.7
Total hardness (mg l^{-1})	13-135	55 -65	65 -72	65.1-110	175.0	110
Calcium (mg l^{-1})	10.02-24.5	10.02 -14.03	14.3 -18.2	16.03 -26.05	26.0	26.05
Magnesium (mg l^{-1})	4.9 -17.1	7.3 -8.5	6. -8.2	6.1 -10.9	26.8	10.9
Silicate (mg l^{-1})	3.2 -4.4	3 -5.1	3. -4.8	5 -5.2	3.5	5.0
Total iron (mg l^{-1})	0.17 -0.55	0.23 -0.60	0.2 -0.5	0.20 -0.22	0.21	0.20
Nitrate (mg l^{-1})	0.04	0.03 -0.08	0.02 -0.04	0.02	0.08	0.02
Phosphate (mg l^{-1})	0.003 -0.006	0.003 -0.006	0.003 -0.004	0.003 -0.02	0.018	0.003
DOM (mg l^{-1})	1.5 -2.9	1.3 -2.6	1. -2.4	1.2 -2.9	1.4	2.9
Gross production (mg C m^{-3} day^{-1})	750	999.6	500.4	999.6	999.6	-
Net production (mg C m^{-3} day^{-1})	300	900	300	900	300	-
Respiration (mg C m^{-3} day^{-1})	600	300	300	300	900	-

as moderately soft (55-110 mg l^{-1}) whereas Sidzu River can be placed under hard water category (175 mg l^{-1}). Gurumayum *et al.* (2001) reported moderate hardness for water from the river Subansiri in Arunachal Pradesh and much lower values from the rivers of Meghalaya (25 to 64.3 mg l^{-1}). Calcium and magnesium content of the water varied with in a wide range of 10.02-26.05 mg l^{-1} and 4.9- 26.8 m gl^{-1} respectively. Sidzu River has the maximum Ca and Mg content whereas lowest values were reported from the Doyang River. Singh *et al.* (2010) also reported similar values of Ca and Mg from the rivers of Manipur.

In the present observation, nitrate (0.02-0.08 mg l^{-1}) and phosphate values (0.003-0.02 mg l^{-1}) were low in all the rivers of the state and this indicate that there is little impact of anthropogenic activities in the rivers. Similar observations were also reported from other north-eastern states by Singh *et al*. (2010) from the rivers of Manipur, Pathak *et al.* (2001b) from the tributaries of Brahmaputra in Arunachal Pradesh and Gurumayum *et al*. (2002) from the rivers of Meghalaya. Silicate concentration fluctuated between 3-5.2 mgl^{-1}. Tezu River has the highest concentration of silicate, however the value remained almost constant during the study period (5-5.2 mg l^{-1}). Gurumayum *et al*. (2002) reported almost similar range of silicate from the rivers of Meghalaya (4.4 to 8.4 mg l^{-1}) whereas Nath (2001), reported a much higher silicate content from the river Narmada (13.8-19.4 mg l^{-1}).

Generally, river sediments are dominated by sand. Soils of the rivers of Nagaland were also of sandy type (90-98%). Percentage composition of silt varied between 0-8% and clay percentage was almost constant during the study (2%). Except the rivers Doyang and Sidzu, the pH of the sediments were below 7 and Tserang River has the lowest pH. Overall pH of the bottom sediments of the rivers of Nagaland varied within 6.0-7.5. Pathak *et al*. (2001b) also reported similar soil types and pH values (6.7-7.2) from the different stretches of river Mahanadi, but a more alkaline pH (7.0-7.5) from the tributaries of river Brahmaputra.

Gross phytoplankton productivity of the rivers varied between 500-999.6 mg C $m^{-3}day^{-1}$, Net productivity was highest in Dikhu and Tezu and have similar values (900 mg C m^{-3} day^{-1}). Doyang, Tserang and Sidzu had constantly low values (300 mg C m^{-3} day^{-1}). Pathak (2001) observed such lower productivity values in the tributaries of river Brahmaputra (148.67-197.5 mg C m^{-3} day^{-1}). A much lower value (111.72-374.4 mg C m^{-3} day^{-1}) was observed by Gurumayum *et al.* (2001b) from Subansiri River, Arunachal Pradesh.

Range of percentage composition of different biotic communities in different rivers of Nagaland is presented in Table 2. Plankton population in the rivers was low (18-282 ul^{-1}) and mostly dominated by phytoplankton (94.9-100%). Maximum plankton population was observed in Tezu whereas minimum in Doyang River. Except Tezu and Sidzu rivers, plankton population were very low in other rivers. Similar low plankton density was also reported by Gurumayum *et al*. (2001) from the river Subansiri (21-144 u l^{-1}) and a much lower value

(10-34 u l^{-1}) from the rivers of Meghalaya. Out of the 38 types of plankton observed, 34 genera were phytoplankton (Cyanophyceae - 4, Bacillariophyceae - 18 and Chlorophyceae - 12) and only four groups of zooplankton (*Diflugia* sp., *Daphnia* sp., Ciliates and *Nebela* sp.) were represented. Bacillariophyceae was the most dominant group in all the rivers (51-84.9%) followed by Chlorophyceae (8-34.5%) and Cyanophyceae (0-13.8%). Dominance of Bacillariophyceae in total plankton count in the hill streams was also noticed by Pathak *et al*. (2001b) from the river Brahmaputra and Gurumayum *et al.* (2000) from the rivers of Arunachal Pradesh (2001) and Meghalaya (2002). Higher plankton density was reported from other lotic systems like river Ganga (110-445 u l^{-1}) by Asif (1998) and in Damodor (16-604 u l^{-1}) by Banerjee (1998). However, much higher values were reported by Khan *et al.* (1998) from river Ganga (400-3900 u l^{-1}) and Jhingran and Pathak (1998) reported 88840 u l^{-1}. Since phytoplankton and zooplankton are largely at the mercy of water currents, they tend to be more prevalent in lentic waters than in rivers or streams. Generally, hilly rivers have lower plankton count due to the fast currents and unavailability of residence time to allow biomass to multiply, as they are transported downstream (David Allan, 1996).

Periphyton population varied between 13100-180500 unit cm^{-2} in the rivers. Maximum density was observed in Tezu River (180500 unit cm^{-2}) whereas minimum was seen in Doyang River (13100 unit cm^{-2}). Winter season showed the highest density of periphyton in Doyang, Dikhu and Tserang rivers. A much-lower value (1441 unit cm^{-2}) was observed by Singh *et al.* (2003) in a man-made lake in Arkavathi River. However, Gurumayum *et al.* (2000) observed similar values from the hill streams of Arunachal Pradesh (7107-85642 unit cm^{-2}). Altogether 32 species of periphyton belonging to Cyanophyceae (5), Bacillariophyceae (20) and Chlorophyceae (12) were recorded during the study. Similar to plankton, Bacillariophyceae showed overall dominance (71.4-99.2%) in all the rivers except Zunki where Bacillariophyceae contributed only 12.8% of total count. Diatom population was maximum throughout the study in Tezu River (90-99.2%). Percentage contributions of Cyanophyceae in the rivers were very low (0-10.3%) and that of Chlorophyceae was 0-76.9%. Percentage contribution of Chlorophyceae was maximum in Zunki River (76.9%). Dominance of diatom in most of the cases may be attributed to their non-sessile free-floating nature. Similar observation was also noticed by several other workers (Daimari *et al.,* 2002; Kawosa, 2001; Singh *et al.,* 2010). Some animal communities were also observed within periphyton communities representing 0-1.2% of the total periphyton count.

Generally, in lotic ecosystem periphyton population is more and plays an important role in productivity of water body. Periphyton count (13100-180,500 unit cm^{-2}) in the rivers were much greater than plankton count (50-165 u l^{-1}), which showed typical hill stream environment. In hill streams, periphyton is the main primary producer and takes over the function of plankton by occupying an important niche in the food chain. Decrease in total plankton count was compensated by increase in the density of periphyton communities. Algae are generally regarded as useful tools in pollution monitoring. Presence of *Oscillatoria, Spirulina, Chlorella*, *Melosira* and *Synedra* were identified as indicators of organic pollution (Goel, 2006). However, absence or almost negligible presence of pollution tolerant species and low Cyanophyceae count in all the rivers proved an affinity towards oligotrophic rather than eutrophic condition of the water.

The macrozoobenthos in the rivers ranged between 159-508 nos. m^{-2}. Maximum was observed in Dikhu River whereas minimum in Doyang River. In Sidzu, Tezu and Zunki rivers, only insect larvae represented the macro-benthic

Table 2. Range of percentage composition of different biotic communities in different rivers of Nagaland

Name of the River	Doyang	Dikhu	Tserang	Tezu	Sidzu	Zunki
Phytoplankton %						
Cyanophyceae	0 -12	0 -6.1	1.9-13.8	1.7-2.5	3.2	0
Bacillariophyceae	66.7-4.9	56.7-82.1	51.7-81.1	75-78.7	62.8	80
Chlorophyceae	8 -33.3	12.8 -34.8	15.1-34.5	8.3 -19.1	31.6	16.4
Sub-total	96 -100	94.9-100	95-100	95.8-99.5	97.6	. 98.2
Zooplankton %	0-4	0-5.1	0-5	0.5- 4.2	2.4	1.8
Plankton (μl^{-1})	18 -91	39-84	29-63	48-282	152	55
Periphyton %						
Cyanophyceae	0.9 -1.7	0-1.1	1.1-2.6	0.8-1	1.3	10.3
Bacillariophyceae	75-1.8	80.8-91.5	71.4-7.9	90-99.2	87.7	12.8
Chlorophyceae	7.3 -25	8.5-18.3	0-26.2	0-8.7	10.3	76.9
Animal communities	0-1.2	0	0-1.1	0-0.3	0.7	0
Total periphyton (u cm^{-2})	13100 -86000	62400-88500	42000-77000	79200-180500	81760	97500
Benthos						
Mollusca %	0	13.4-37.5	0-37.5	0	0	0
Insect larvae %	82.9-100	62.3-86.6	62.5-100	100	100	100
Turbellaria %	27.1	0	0	0	0	0
Total benthos (no. m^{-2})	159 -478	255 -508	256-350	350	318	382

fauna. Pre-monsoon season showed the lowest macro zoobenthos population in Doyang, Dikhu and Tserang, whereas the highest value was observed during winter. Commonly encountered zoobenthos were molluscans, turbellarians and insect larvae (Ephemeroptera, Coleoptera, Plecoptera, Diptera, Odoneta and Hemiptera). Insect larvae dominated (72.1-100%) over molluscs (0-27.9%) in all the rivers. Turbellarians were found only in Doyang River contributing to 27.1% of the total benthos count. Similar observation of low benthos density (162-290 no. m^{-2}) were also reported in tributaries of river Brahmaputra by Pathak *et. al*. (2001). Further, the present findings support the contention of Patrick (1970) that the rigorous and unpredictable stream environment is largely responsible for low equitability and low diversity in benthic community.

The rivers in Nagaland can be classified as moderately productive on the basis of phytoplankton productivity with average net primary productivity value varying between 300-900 mg C m^{-3} day^{-1}. Lower nutrient concentrations, high dissolved oxygen and sparse zooplankton and phytoplankton density indicates oligotrophic condition of the rivers. Dominance of periphyton over plankton population reveals the true rhiophilic condition of the streams. Presence of some pollution tolerant species during the study reflected an influx of rainwater from the domestic areas. On the basis of above findings of biotic and abiotic parameters, it can be inferred that the rivers of Nagaland investigated during the present study, are quite free from the impact of anthropogenic activities.

Acknowledgements

The authors are grateful to the Indian Council of Agricultural Research, New Delhi for financial assistance rendered as part of an A. P. Cess Fund project and to the Director, Central Inland Fisheries Research Institute (ICAR), Barrackpore for providing necessary facilities.

References

APHA 1989. *Standard methods for the examination of water and wastewater,* 17th edn., American Public Health Association, Washington DC, 1268 pp.

Asif A. Khan, Aftab Alam and Rajeev K. Gaur 1998. Seasonal variation in the abundance and composition of phytoplankton in the river Ganges at Narora, U. P. *J. Inland Fish. Soc. India*, 30 (1): 79-86.

Banerjee, R. K., Mukhopadhyay, M. K., Pandit, P. K., Karmakar, H. C., Mitra, K, Chatterjee, S. K., Das, B. B. and Sengupta, A. 1998. *River Damodar and its environment, Bulletin No. 79.* Central Inland Capture Fisheries Research Institute, Barrackpore, India, 32 pp.

Daimari, P., Gurumayum, S. D., Choudhury M. and Bhattacharjya B. K. 2002. Seasonal abundance of periphyton community in Kameng River, Arunachal Pradesh. In: Sugunan, V. V., Vinci, G. K., Katiha, P. K. and Das, M. K. (Eds.), *Fisheries enhancement in inland waters-Challenges ahead*. Central Inland Capture Fisheries Research Institute, Barrackpore, India, p. 95-99.

David Allan, J. 1996. *Ecology - structure and function of running water*. Chapman & Hall Publication, London, 388 pp.

Desikachary, T. V. 1959. *Cyanophyta,* ICAR Monograph on Algae. ICAR, New Delhi, 686 pp.

Edmondson, W. T. 1959. *Freshwater biology*, 2nd edn. John Wiley & Sons Inc., New York, 1248 pp.

Ellis, M. M. 1937. Detection and measurement of stream pollution. *Bull. U. S. Bur. Fish. Washington*, 48: 365-437.

Garder, T. and Gran, H. H. 1927. Investigation on the production of plankton in Oslo Fjord. *Rapp. P, V. Reun. Cons. Perm. Int. Explor. Mer*., 42(1 &2): 1-48.

Goel, P. K. 2006. *Water pollution - causes, effects and control*. New age international Pvt. Ltd., New Delhi, 418 pp.

Gurumayum, S. D., Daimari, P. and Choudhury, M. 2000. Abundance and quality composition of periphyton communities in hill stream of Arunachal Pradesh. *J. Environ. Res*., 10 (2): 113-116.

Gurumayum, S. D., Daimari, P., Goswami, B. K. and Choudhury, M. 2001. Ecology of river Subansiri at Arunachal Pradesh. *J. Inland Fish. Soc. India,* 33(2): 50-54.

Gurumayum, S. D., Daimari, P., Goswami, B. S., Alok Sarkar and Choudhury, M. 2002. Observations on physico-chemical qualities of water and plankton of rivers in Meghalaya, *J. Inland Fish. Soc. India*, 34(2): 36-42.

ISRO 2010. *National Wetland Atlas: Nagaland,* SAC/RESA/AFEG/NWIA/ATLAS/20/2010, Space Applications Centre (ISRO), Ahmedabad, India, 116 pp.

Iyengar, M. O. P. and Desikachary, T. V. 1981. *Volvocales*, ICAR Monograph on Algae, ICAR, New Delhi, 532 pp.

Jhingran, A. G. and Pathak, V. 1988. Impact of man-induced environmental modification on productivity potential and energy dynamics of river Ganga. *J. Inland Fish. Soc. India*, 20 (2): 43-53.

Kawosa, M. S. 2001. Occurrence of periphyton on artificial substrate in a rural lake, Kashmir. *Geobios*, 28 (2 and 3): 137 –139.

Khan, M. A., Panwar, R. S., Mathur, A. and Rekha Jetly 1998. Studies on plankton communities and primary production in middle stretch of river Ganga in context of cultural eutrophication. *J. Inland Fish. Soc. India*, 30 (10): 47-68.

Laishram Kosygin, Haobijam Dhamendra and Rajkumari Gyaneshwari 2007. Pollution status and conservation strategies of Moirang River, Manipur with a note on its aquatic bio-resources. *J. Environ. Biol*., 28(3): 669-673.

Nath, D. 2001. Water and soil characteristics of the Narmada Estuary before commissioning of Sardar Sarobar dam. *J. Inland Fish. Soc. India*, 33 (2): 37-41.

Needham, G. J. and Needham, P. R. 1966. *A guide to freshwater biology*, 5th edn. Holden Day Inc., Sanfransisco, 108 pp.

Pathak, V., Mahavar, L. R. and Sarkar, A. 2001a. Ecological status and production dynamics of stretch of river Mahanadi. *J. Inland Fish. Soc. India*, 33 (1): 25-31.

Pathak, V., Sarkar, A., Mahavar, L. R. and Bhattacharjee, B. K. 2001b. Ecological status and fish production potential of Siang, Dibang and Lohit - the three forerunners of river Brahmaputrra. *J. Inland Fish. Soc. India*, 33 (2): 23-28.

Patrick, R. 1970. Benthic stream communities. *Am. Scient*., 58(5): 546-549.

Philipose, M. T. 1967. *Chlorococcales*, ICAR Monograph on Algae, ICAR, New Delhi, 356 pp.

Ramanathan, K. R. 1964, *Ulotricals*, ICAR Monograph on Algae, ICAR, New Delhi, 118 pp

Singh M. R., Gupta Asha and Beeteswari, K. H. 2010. Physico-chemical properties of water samples from Manipur River System, India, *J. Appl. Sci. Environ. Manage.*, 14 (4): 85-89.

Taylor, E. W. 1949. *The examination of water and water supplies*. J. and A Churchill Ltd., Philadelphia: Blakiston, London, 819 pp.

WHO 1995. *World Health Organization. Guideline for drinking water quality*. WHO, Geneva, 127 pp.

Date of Receipt : 09.04.2012
Date of Acceptance : 27.08.2013