Studies on annual variation in Species diversity of Cyanobacteria in four rivers of Western Ghats region, Karnataka, India

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ABSTRACT

The present studies were carried out to know the occurrence, distribution, species richness and diversity of Cyanobacteria in relation to water chemistry in four different river systems such as Netravati of Dharmasthala, Kumaradhara of Subramanya, Sita and Shambhavi of Karkala of Western Ghat region for two consecutive years in the month of October 2012 and 2013 respectively. A total of 41 species belonging 16 genera were observed in these four rivers during the study period. The leaf/litter yielded maximum number of species. Maximum number of 21 species was identified in Netravati river followed by 18 species in Kumaradhara river 14 species in Sita river and 13 species in Shambhavi river throughout the study period. In the year 2012, 13 species each were identified both in Netravati river and in Kumaradhara river while nine and eight species were identified in Sita river and Shambhavi river respectively. While in the year 2013, maximum number of 18 species was identified in Netravati river followed by 16 species in Kumaradhara river, 11 species in Sita river and 09 species in Shambhavi river. *Oscillatoria limosa* was the most dominant species which was present in all the rivers in both the years, but abundant in Netravati and Kumaradhara river. *Microcystis aruginosa* was present in all the rivers except during first year in Netravati and Shambhavi rivers. Some species were particular to some rivers. Even though some species were rare in some rivers, however those were frequent in some other rivers. *Microcystis scripta* was one of the rare species identified in Sita river only during 2013. Occurrence and species richness was more in such conditions where pH was slightly alkaline and dissolved oxygen content was more. However bloom condition was not reached.

Keywords: *Cyanobacteria, Rivers, Species diversity, Rare species, Western Ghats.*

INTRODUCTION

Cyanobacteria are photosynthetic prokaryotes found in most places and other aquatic systems. Since they have the ability to grow in different environments with little moisture and light, they can be found in almost all habitats. The species diversity, annual and seasonal variation of the cyanobacterial assemblage were investigated in different habitats namely, temple ponds (Swain *et al.,* 1993; Maya *et al.,* 2000; Joishi M.S, 2009), paddy field (Anand, 1988; Madhusoodan and Dominic, 1996; Song *et al.,* 2005; Joishi M.S, 2009), estuaries (Thajuddin and Subramanium, 2005; Verspagen *et al*., 2006; Joishi M.S, 2009), lakes, rivers and streams (Smith, 2003; Joishi M.S, 2009), ponds and sulfur spring (Santra, 1990; Jing *et al.,* 2006; Joishi M.S, 2009). They also play a vital role in the maintenance and build up of the fertility of soil (Roger and Watanabe, 1986).The objective of this study was to determine the cyanobacterial diversity,species richness in comparison with four different rivers such as Netravati of Dharmasthala, Kumaradhara of Subramanya, Sita and Shambhavi of Karkala of Western Ghats region and discussed in relation to physico-chemical factors of water for two consecutive years.

Table 1. Location and place of sample collections of four rivers of Western Ghats region

S. No.	River	Western Ghat region	Location and place of sample collection
1	Netravati	Dharmastala	12º59/ N and 75º12/ E, Dharmastala
2	Kumaradhara	Subramanya	12º38/ N and 75º30/ E, Subramanya
3	Shambhavi	Karkala	13º12/ N and 75º58/ E, Sanoor
4	Sita	Karkala	13º30/ N and 75º59/ E, Hebri

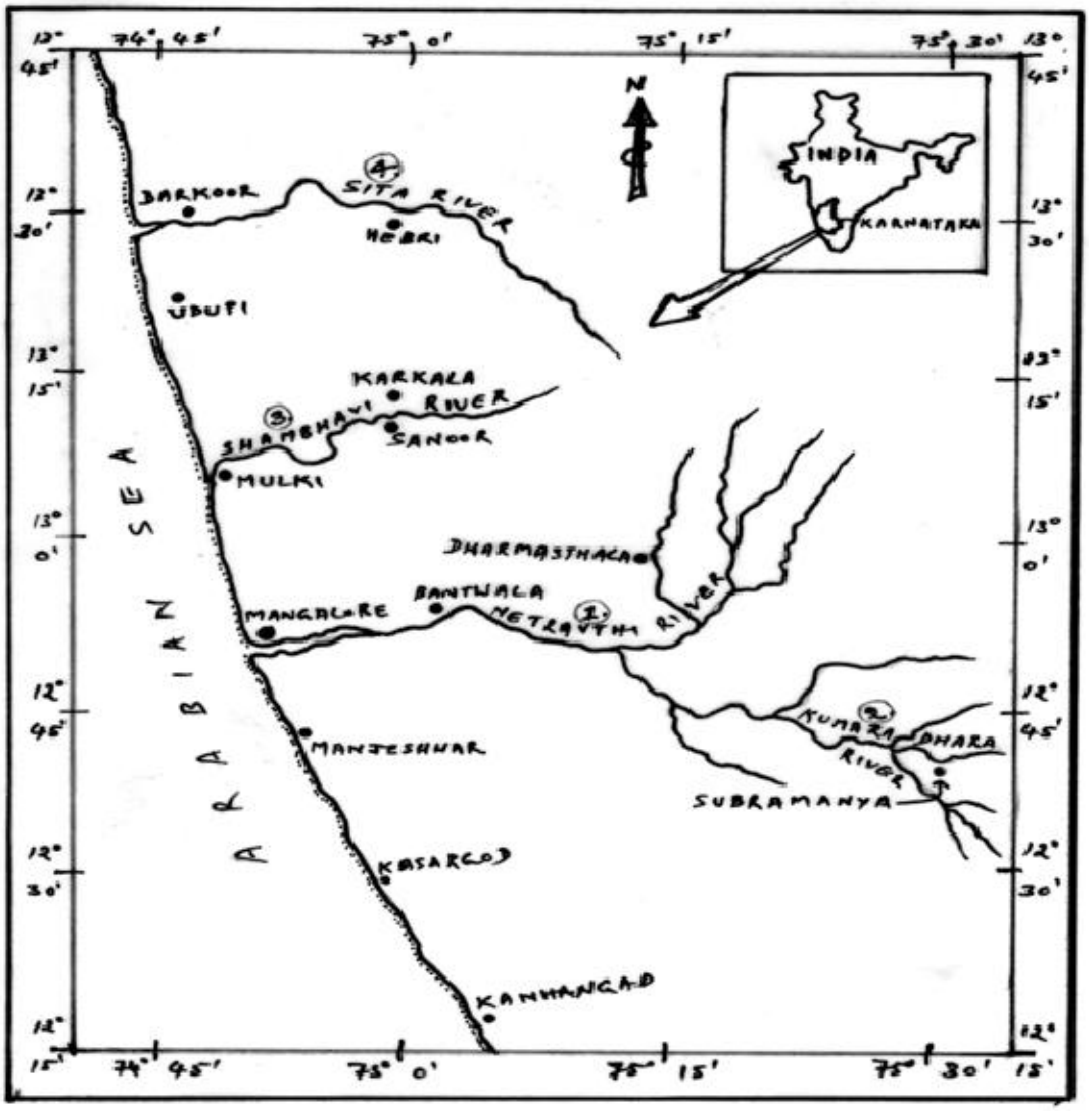

Figure 1. Map showing four rivers of the study in the Western Ghats region
1. Netravathi 2. Kumaradhara 3. Shambhavi 4. Sita

MATERIALS AND METHODS

The present study was carried out in four rivers of the Western Ghats region such as Dharmastala, Subramanya and Karkala to identify the species of cyanobacteria and to know their occurrence, distribution, species diversity and species richness in relation to water chemistry. The four rivers, location and place of sample collection are as mentioned in the table 1 and as shown in the figure 1. The work was carried out for two consecutive years in the month of October 2012 and 2013 respectively.

Sample collection

Sampling materials containing cyanobacteria were collected by using nylon plankton net, on a clear day before noon and from the following substrata: rock fragments, leaf/ litter, twigs, fruit walls, molluscan shells, thermocol pieces etc. along with water in 15 ml specimen vials.

The samples were immediately fixed in the study site using 5 % formalin. From the collected mass they were isolated by the dilution method and surface plating technique (Anand *et al*., 1986; Anand and Hopper, 1987).

Observation and Identification of the species

The isolated species were taken on a clean glass slide and were observed under research microscope at 45 x and 100 x magnification and were identified with the help of standard monographs, research papers and relevant literatures (Desikachary, 1959; Anand *et al*., 1986; Anand and Hopper, 1987; Shaji and Panikker, 1994; Komareck and Anagnostidis, 1998; John Wehr and Robert Sheath. 2003; Gupta *et al*., 2006: Vardhana, 2008; Khuntia, 2011). Camera Lucida drawings of identified species were drawn.

Physico-chemical analysis

The water samples collected from each river body from three locations in the October month of the corresponding year, in a well cleaned plastic can of 5 liter capacity brought to the laboratory for physico-chemical analysis. Surface water temperature and pH were measured and dissolved oxygen concentration of the water sample was fixed on the study site. The quantitative analysis of different physico-chemical factors such as dissolved O_2, free CO_2, alkalinity, total hardness, dissolved organic matter, nitrite, nitrate, ammonium and phosphate for each water sampling was carried out by employing standard methods with the reference of APHA (1998), Trivedy and Goel (1986) and Walkeel and Riley (1956). Three trials have been done and mean value has been taken for the study. Comparative study of these rivers was done based on the above results. Species occurrence, distribution and richness were studied in relation to water chemistry of the rivers

RESULT

The study of various physico-chemical parameters such as temperature, pH, dissolved oxygen, free carbon dioxide, alkalinity, calcium hardness, total hardness, nitrite, nitrate, ammonium, phosphate and dissolved organic matter in four rivers ranged as presented in the Figures 2 to 7.

In the present study the average water temperature of the river ranged between 28.3 in Kumardhara river and 29.0ºC in Netravathi river in both the years; pH ranged between 7.4 both in Netravathi river during 2012 and in Kumardhara river during 2013 and 7.9 in Shambhavi river in both the years ; dissolved oxygen concentration ranged between 6.1 mg l^{-1} during 2012 in Shambhavi river and 8.3 mg l^{-1} during 2013 in Kumardhara river ; free carbon dioxide concentration ranged between 16 mg l^{-1} during 2013 in Kumardhara river and 41 mg l^{-1} during 2012 in Shambhavi river; alkalinity ranged between 35 mg l^{-1} during 2013 in Netravathi river and 52.0 mg l^{-1} during 2012 in Shambhavi river; total hardness ranged between 100.5 in Sita during 2013 and 115.5mg l^{-1} during 2012 in Shambhavi river; calcium hardness ranged between 11 in Kumardhara during 2013 and 17.8mg l^{-1} during 2012 in Shambhavi river; nitrite concentration ranged between 0.1mg l^{-1} during both the years in all the three rivers except Netravathi river and 0.4 mg l^{-1} during 2013 in Netravathi river; nitrate concentration ranged between 2.0 mg l^{-1} during 2013 in Sita and Shambhavi river 4.7 mg l^{-1} during 2013 in Netravathi river; ammonium concentration ranged between 0.1mg l^{-1} during 2013 in all the four rivers and 0.33 mg l^{-1} during 2012 in Kumardhara river ; phosphate concentration ranged between 0.12mg l^{-1} during 2012 in Shambhavi river and 0.20 mg l^{-1} during2012 in Kumardhara river; dissolved organic matter ranged between 2.7 mg l^{-1} during 2012 in Shambhavi river and 3.80 mg l^{-1} during 2013 in Sita river.

A total of 41 species belonging 16 genera were observed in these four rivers during the study period (Table 2). The identified species were found attached to leaf/ litters, rock fragments, twigs, certain fruit wall and molluscan shells. The leaf/litter yielded maximum number of species. Out of a total of 41 species, the maximum number of species belonged to *Oscillatoria* (11) followed by *Microcystis* with seven species, *Phormidium* and *Scytonema* four each, *Gloeocapsa* three, *Aphanocapsa* two, and one each from *Anabaenopsis, Aphanothece*, *Calothrix*, *Camptylonemopsis, Chlorogloea, Dactylococoopsis*, *Lyngbya*, *Rivularia, Scytonematopsis and Synechococcus.*

In the first year (2012) 36 species (Table 2 and Figure 8 and 9) and in the second year (2013) 32 species were observed. In the second year out of 36 species of the first year, only 27 species were present and nine species namely *Anabaenopsis arnoldii, Aphanothece clathrata, Camptylonemopsis pulneyensis, Gloeocapsa punctata, Microcystis viridis, Oscillatoria acuta, Oscillatoria animalis, Oscillatoria corallinae* and *Scytonematopsis kashyapi* (species no.1, 4. 6. 11. 18, 19, 22, 23 and 35 from the table no. 2) were absent. However, five new species, *Microcystis scripta, Phormidium perpurascens, Scytonema fremyii, Scytonema subile,* and *Scytonema zellarianum* were

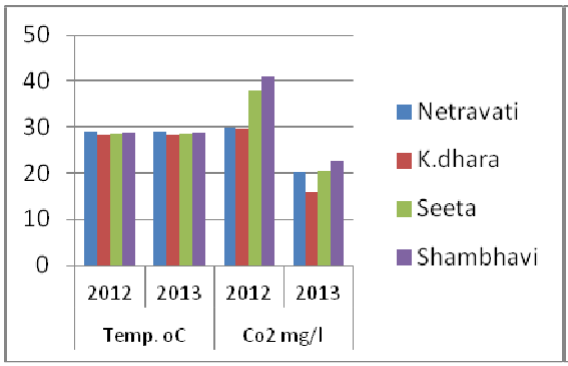

Figure2. Temperature and Carbon dioxide

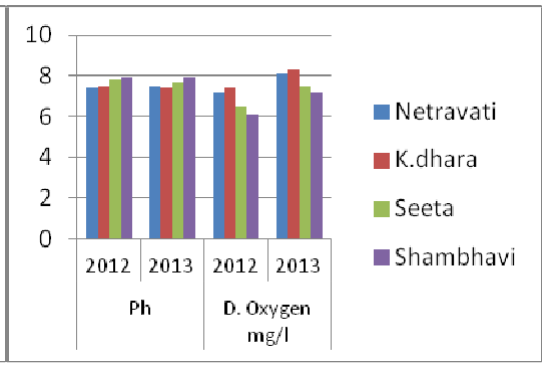

Figure 3. Ph and Dissolved Oxygen

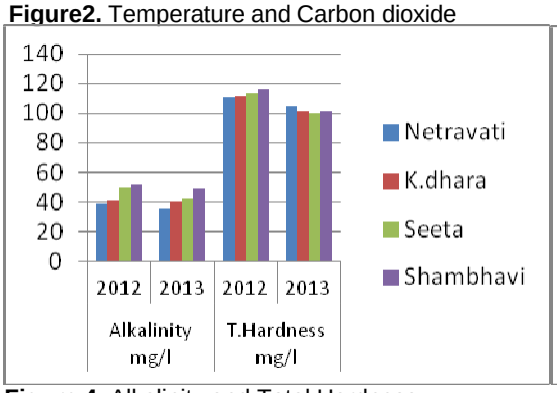

Figure 4. Alkalinity and Total Hardness

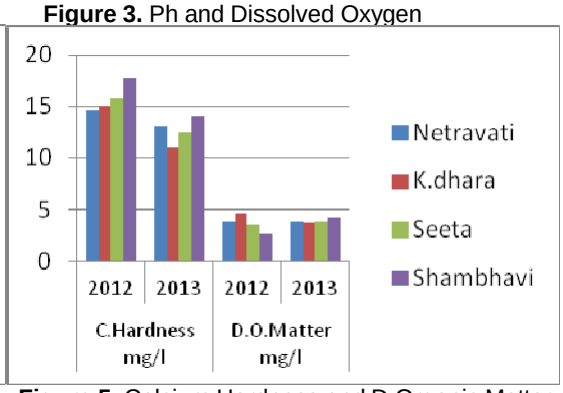

Figure 5. Calcium Hardness and D.Organic Matter

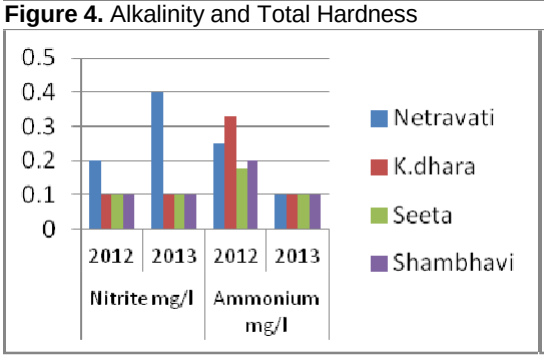

Figure 6. Nitrite and Ammonium

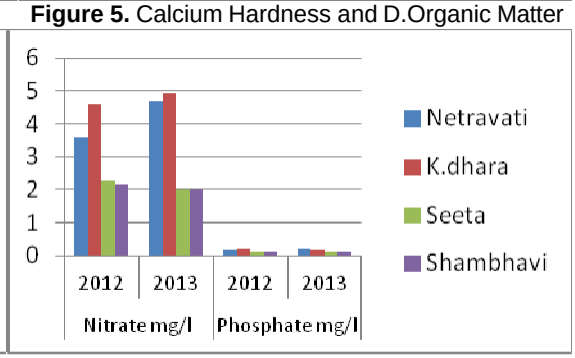

Figure 7. Nitrate and Phosphate

Figures 2 to 7 shows the variations in the values of different parameters in four rivers during the study period 2012 and 2013.

added (species no.37 to 41 from the table no. 2 and Figure 10) to the previous year's 27 species.

Maximum number of 21 species was identified in Netravati river followed by 18 species in Kumaradhara river 14 species in Sita river and 13 species in Shambhavi river throughout the study period. If it is focused on year wise identification species number was more in second year in all the rivers compared to first year and Maximum number of 18 species was identified in Netravati river followed by 16 species in Kumaradhara river, 11 species in Sita river and 09 species in Shambhavi river in second year and in the first year 13 species each were identified both in Netravati river and in Kumaradhara river while nine and eight species were identified in Sita river and Shambhavi river respectively.

Oscillatoria limosa was the most dominant species which was present in all the rivers in both the years, but abundant in Netravati and Kumaradhara river. *Microcystis aruginosa* was present in all the rivers except during first year in Netravati and Shambhavi rivers. *Chlorogloea microcystoides* was present in both Netravati and Kumaradhara river only and more in Netravati river in the second year. *Chlorogloea microcystoides and Phormidium anomola* were identif ied during both t he years only i n Netravati and Kumaradhara river.

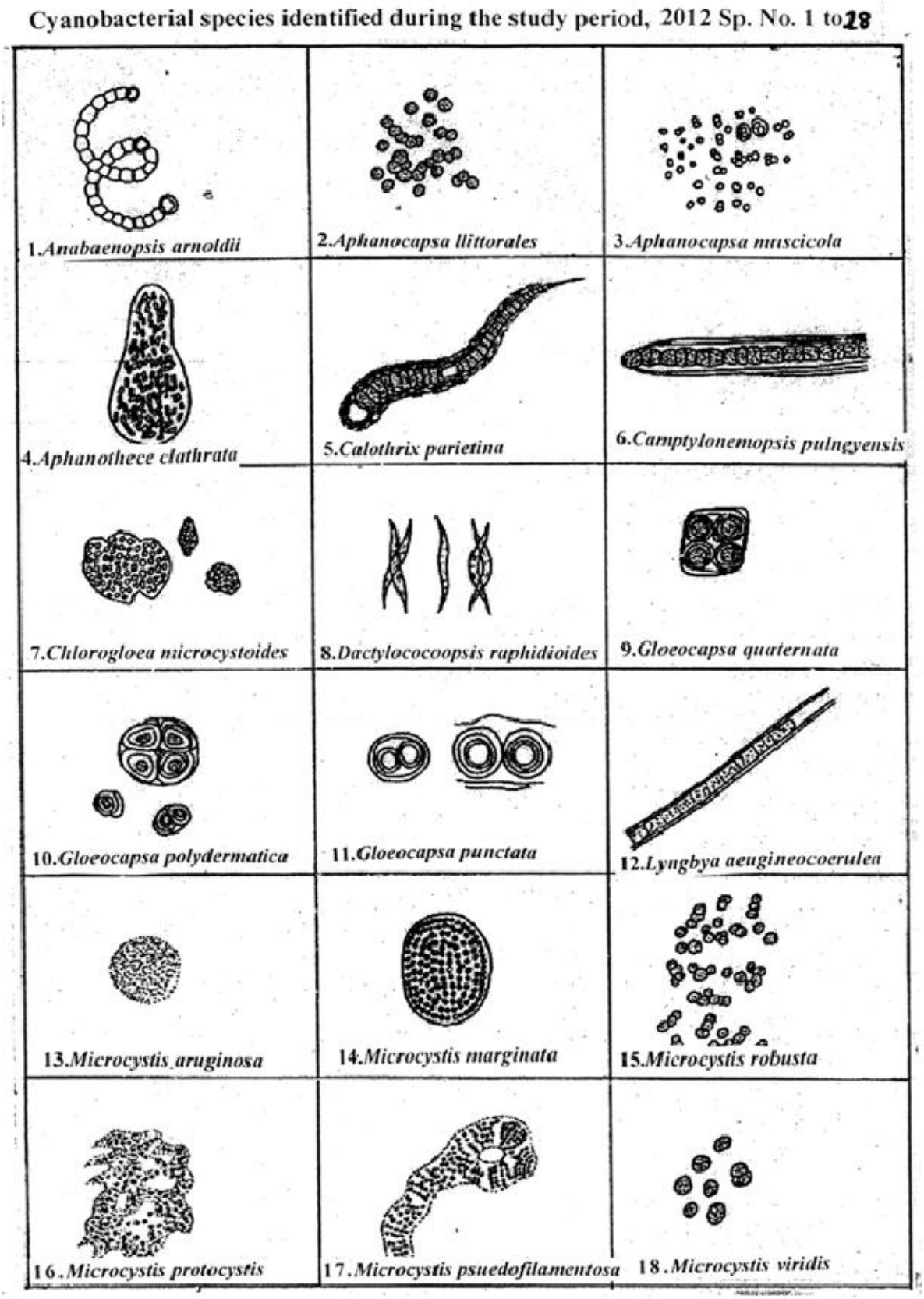

Figure 8. Species of Cyanobacteria identified in four rivers of Western ghat region during study period 2012.

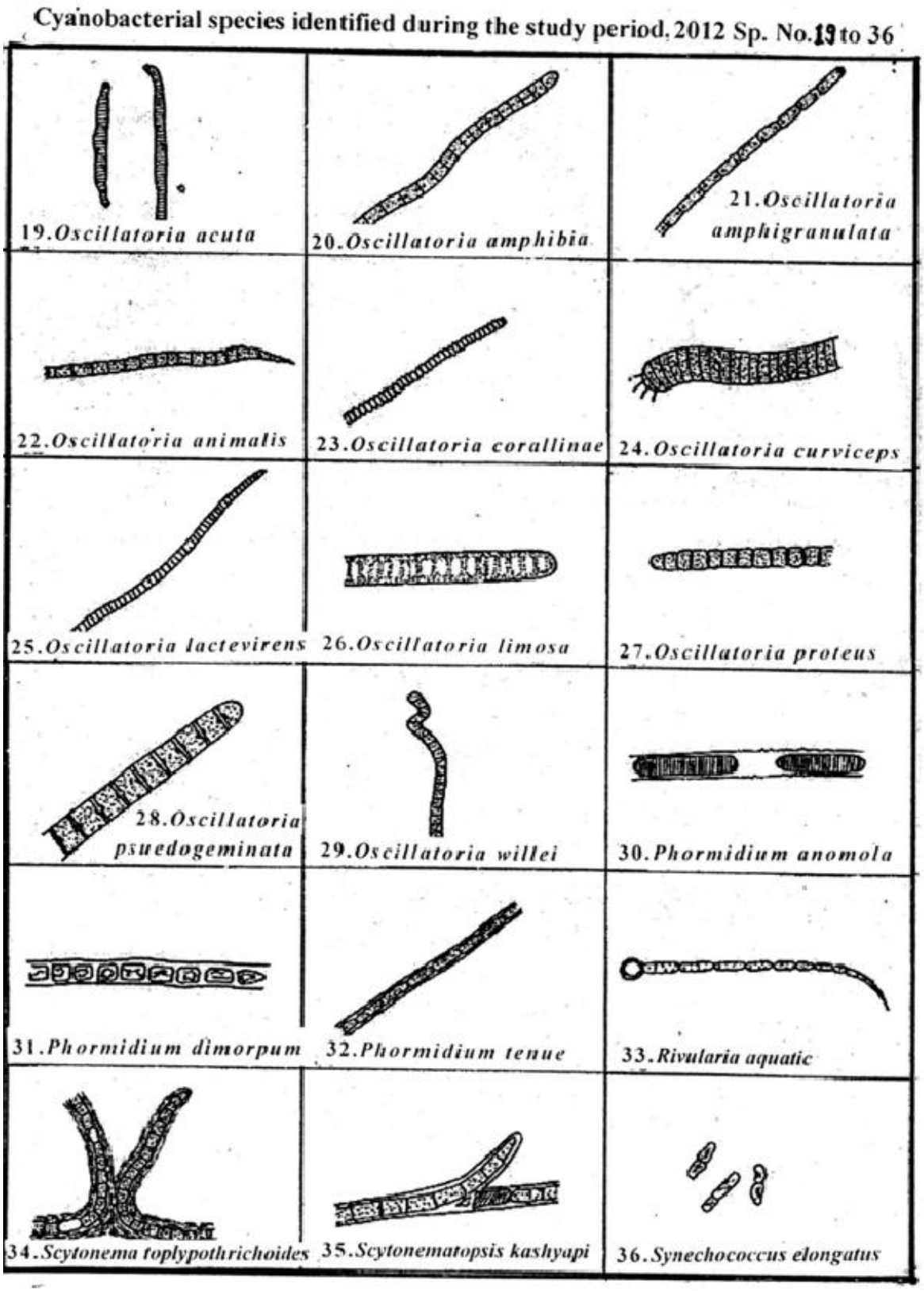

Figure 9. Species of Cyanobacteria identified in four rivers of Western ghat region during study period 2012.

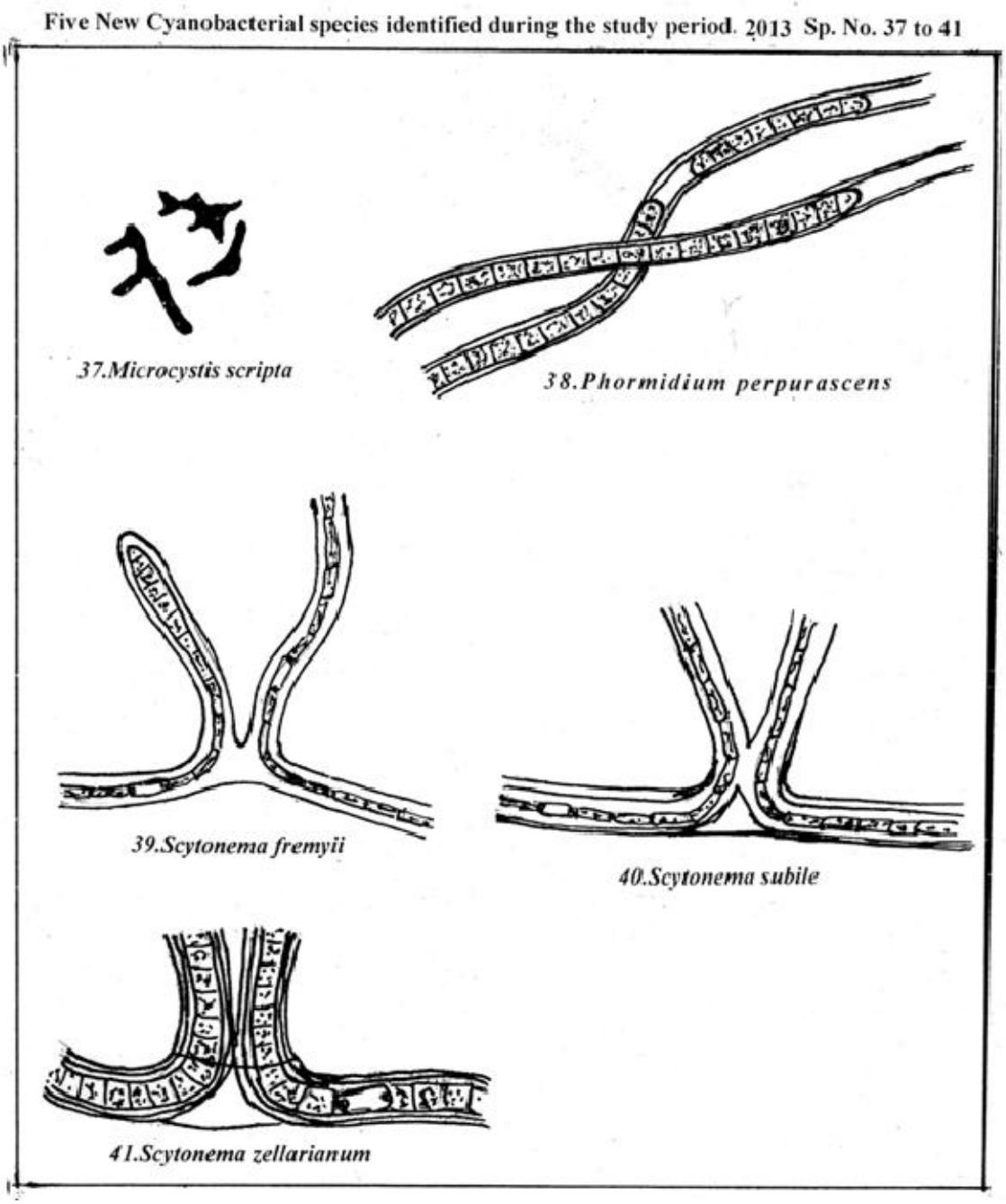

Figure 10. Five new Species of Cyanobacteria identified in 2013. Sp. No. 37 in Sita River as rare species, Sp. No. 38 – 41 in Kumaradhara river and Sp. No. 40 also in Netravathi river.

Oscillatoria amphibia and *O.amphigranulata* were more in both the years in Netravati river, however rarely observed in Sita and Shambhavi rivers only in second year. *O. psuedogeminata* and *O. wille*, both were more in Netravati river during both the years, however *O. psuedogeminata* was more in Shambhavi river and rarely seen in Sita river in second year only. Species no. 1, 9, 18, 22 and 31 from table 2 were particular to Netravati river. Species no. 10, 15, 23, 35 and 37 from table 2 were particular to Sita river and Species no.37 *Microcystis scripta* was very rare. Species no. 3, 4, 6, 11 and 27 from table 2 were particular to Shambhavi river. A maximum number of eight species, species no. 5, 12, 16, 19, 33, 38, 39 and 41 from table 2 were particular to Kumaradhara river only.

Table 2. Species identified with its richness, total number of species in each year in four different rivers and altogether number of species in each year during study period. Five new species (species no. 37-41) identified only during second year of the study, in 2013
+ = Very few, ++ = Few, +++ = Moderate, ++++ = More, R= Rare, Ab= Absent.

Sl No.	Species identified	Rivers							
		Netravati		Kumradhara		Sita		Shambhavi	
		2012	2013	2012	2013	2012	2013	2012	2013
1	*Anabaenopsis arnoldii*	++	Ab	Ab	Ab	Ab	Ab	Ab	Ab
2	*Aphanocapsa llittorales*	Ab	++++	++	+	Ab	+	Ab	Ab
3	*Aphanocapsa muscicola*	Ab	Ab	Ab	Ab	Ab	Ab	+	+++
4	*Aphanothece clathrata*	Ab	Ab	Ab	Ab	Ab	Ab	+++	Ab
5	*Calothrix parietina*	Ab	Ab	++	+	Ab	Ab	Ab	Ab
6	*Camptylonemopsis pulneyensis*	Ab	Ab	Ab	Ab	Ab	Ab	++	Ab
7	*Chlorogloea microcystoides*	++	++++	++	+	Ab	Ab	Ab	Ab
8	*Dactylococoopsis raphidioides*	Ab	+	Ab	Ab	+	Ab	Ab	Ab
9	*Gloeocapsa quaternata*	++++	+++	Ab	Ab	Ab	Ab	Ab	Ab
10	*Gloeocapsa polydermatica*	Ab	Ab	Ab	Ab	++++	+	Ab	Ab
11	*Gloeocapsa punctata*	Ab	Ab	Ab	Ab	Ab	Ab	+	Ab
12	*Lyngbya aeugineocoerulea*	Ab	Ab	++	+	Ab	Ab	Ab	Ab
13	*Microcystis aruginosa*	Ab	++	++	+++	++	++	Ab	++
14	*Microcystis marginata*	Ab	++	Ab	Ab	++	+	Ab	Ab
15	*Microcystis robusta*	Ab	Ab	Ab	Ab	++++	++	Ab	Ab
16	*Microcystis protocystis*	Ab	Ab	++	++	Ab	Ab	Ab	Ab
17	*Microcystis psuedofilamentosa*	Ab	Ab	++	Ab	Ab	Ab	Ab	+
18	*Microcystis viridis*	++	Ab	Ab	Ab	Ab	Ab	Ab	Ab
19	*Oscillatoria acuta*	Ab	Ab	++	Ab	Ab	Ab	Ab	Ab
20	*Oscillatoria amphibia*	++++	++++	Ab	Ab	Ab	**R**	Ab	Ab
21	*O. amphigranulata*	++++	++++	Ab	Ab	Ab	Ab	Ab	**R**
22	*Oscillatoria animalis*	++	Ab	Ab	Ab	Ab	Ab	Ab	Ab
23	*Oscillatoria corallinae*	Ab	Ab	Ab	Ab	++	Ab	Ab	Ab
24	*Oscillatoria curviceps*	Ab	Ab	++	++	Ab	Ab	++++	+++
25	*Oscillatoria lactevirens*	Ab	+++	Ab	++++	++++	++++	Ab	Ab
26	*Oscillatoria limosa*	++++	++++	+++	++++	+	++	+	+
27	*Oscillatoria proteus*	Ab	Ab	Ab	Ab	Ab	Ab	+++	+++
28	*O. psuedogeminata*	++++	++++	Ab	Ab	Ab	**R**	Ab	++++
29	*Oscillatoria willei*	++++	++++	Ab	Ab	Ab	+	Ab	Ab
30	*Phormidium anomola*	++	+	++	**R**	Ab	Ab	Ab	Ab
31	*Phormidium dimorpum*	++	+	Ab	Ab	Ab	Ab	Ab	Ab
32	*Phormidium tenue*	Ab	++	Ab	Ab	Ab	Ab	++	Ab
33	*Rivularia aquatica*	Ab	Ab	**R**	++	Ab	Ab	Ab	Ab
34	*Scytonema toplypothrichoides*	++	+	Ab	Ab	Ab	Ab	Ab	R
35	*Scytonematopsis kashyapi*	Ab	Ab	Ab	Ab	++	Ab	Ab	Ab
36	*Synechococcus elongatus*	Ab	**R**	++	+++	Ab	Ab	Ab	Ab
37	*Microcystis scripta*	Ab	Ab	Ab	Ab	Ab	**R**	Ab	Ab
38	*P. perpurascens*	Ab	Ab	Ab	++++	Ab	Ab	Ab	Ab
39	*Scytonema fremyii*	Ab	Ab	Ab	++++	Ab	Ab	Ab	Ab
40	*Scytonema subile*	Ab	++	Ab	++++	Ab	Ab	Ab	Ab
41	*Scytonema zellarianum*	Ab	Ab	Ab	+++	Ab	Ab	Ab	Ab
Total no. of Species		**13**	**18**	**13**	**16**	**09**	**11**	**08**	**09**
Altogether No. of Species yearly		**Year 2012 = 36**				**Year 2013 = 32**			

DISCUSSION

The occurrence of maximum number of species in Netravati and Kumaradhara rivers showed that optimum temperature, slightly alkaline pH and more dissolved oxygen concentration favour the species diversity and species richness. This result is in agreement with many workers who reported that cyanobacteria prefer neutral to slightly alkaline pH for their growth (Brock, 1973; Whitton and Sinclair, 1975; Prasad et al., 1978; Hariprasad and Ramakrishnan, 2003; Gowda, 2006; Joishi M.S. 2009). Deep *et al.,* in 2013 was also noticed that total cyanobacterial species showed + correlation with dissolved oxygen levels.

The physico-chemical properties such as pH, salinity, temperature and dissolved oxygen etc. are the very important factors that determine the growth and establishment of cyanobacteria (Anand, 1980; Kaushik, 1987; Chunleuchanon *et al*., 2003). Bhave and Borse (2001) recorded highest number of organisms at pH (7.8) in the Aner river of Jalgaon of Maharastra. Many reports showed that there was a positive correlation between the dissolved oxygen concentration and population of cyanobacteria (Fallon and Brock, 1980; Hosmani and Anita, 1998; Hariprasad and Ramkrishnan, 2003; Joishi M.S. 2009).

The *Oscillatoria* was the dominant genus and species *Oscillatoria limosa* was identified as the dominant and common species in all the rivers in both the years, followed by *Microcystis aruginosa* was identified in all the rivers except in the first year in Netravati and Shambhavi rivers The similar observation was made in Netravati river near Bantwal, Udyavar river in Udupi District and Nandini river in Kateel of Dakshina Kannada District during earlier studies (Joishi M.S., 2009). Occurrence of cyanobacterial species namely, *Microcystis aeruginosa* and *Oscillatoria limosa* were noticed in the Tapajos river (Uherkovich, 1976). *Microcystis aeruginosa* with the other several phytoplanktons was also noticed in the rivers of Portugal (Teles et al., 2006).

Even though it was not reached the bloom condition, in summer season the richness of the dominant species *Oscillatoria limosa* and *Microcystis aruginosa* only may increase more leaving behind other species, due to high dissolved organic matter and may act as a pollution tolerant species in Netravati and Kumaradhara rivers (Hosmani and Mallesh, 1985 Hosmani, 1987). Verspagen*et al.* (2006) observed the *Microcystis* blooms during every summer in the Dutch delta, which was formerly an estuary, later turned into lake. They predicted that flushing with freshwater will suppress *Microcystis* blooms. During the study carried out in West–Naktong river of South Korea, Jung *et al*. (2005) observed the *Microcystis* bloom during the period between May and August and a high biomass was observed during mid May, in the initial stage of the bloom.

The high content of nitrate and phosphate in Netravati and Kumaradhara rivers may also favour the occurrence, growth and richness of cyanobacteria (Dey and Hazra 2005). When the physico chemical parameters data of Netravati and Kumaradhara rivers compare with that of Seeta and Shambhavi rivers, it is revealed that this may be the most favourable environment for the diversity, growth and richness of the species. The similar observations was made by Moreno et al., 2004 and Joishi M.S. 2009.

Microcystis scripta was identified as rare species only in Sita river during 2013. Likewise many different rare species of cyanobacteria have been identified from different rivers of the world (Brittain *et al*., 2000; Fiore *et al*., 2005; Zakaria *et al*., 2006; Hassan et al., 2012).

CONCLUSION

The cyanobacteria contain different biochemical compounds. They show high nutritional quality in terms of protein, carbohydrate,lipids and calorific value. However, overall nutritional value varied between the species (Nagarkar *et al*., 2004; Joishi.M.S.2009). These biochemical compounds also have medicinal value. So such cyanobacterial species also can be collected in large quantity from these rivers, such as Netravati of Dharmasthala, Kumaradhara of Subramanya, Sita and Shambhavi of Karkala of Western Ghats region which may be exploited in large scale as a food reserve and also in the medicinal field.

The pollution tolerant species such as *Oscillatoria limosa* and *Microcystis aruginosa* were abundant during the study period. So it was revealed from the study that in summer, since there may be possibility of increasing in population of these species, leading to formation water bloom and such water may be polluted due to toxic substances and not fit for drinking, domestic and other useable purposes. So precautionary measure should be developed as monitoring and alert framework based on WHO to avoid excess growth than the advisable range.

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