A STUDY ON GROWTH CO-EFFICIENT AND RELATIVE CONDITION FACTOR OF THE MAJOR CARP (*CATLA CATLA)* IN TWO LAKES DIFFERING IN WATER QUALITY

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Abstract. Physico-chemical water quality parameters viz. temperature, pH, alkalinity, turbidity, total solids, DO, BOD, nitrite, nitrate, phosphate, ammonia, and hydrogen sulfide coupled with diversity and density of plankton were studied during different seasons (monsoon, winter, summer) for two consecutive calendar years in two lakes to find out whether differences in water quality are reflected in growth co-efficient and relative condition factor of the major carp, *Catla catla.* Significantly higher levels of nutrients (phosphate, nitrate, nitrite) and ammonia, low plankton diversity, and significantly higher density of cyanophyceae were found in Yennehole lake (YL) compared to Belikere lake (BL). In addition, desmids were conspicuous by their absence in YL in contrast to their presence in BL. Concomitantly, growth factor (b) and relative condition factor (Kn) of *C.catla* were < 3 and < 1 respectively in YL whereas they were close to 3 (or > 3) and >1 respectively in BL in all the seasons in during the study period. The contrasting b and Kn values of the same species in two lakes differing in water quality provide an evidence that deterioration in water quality though not enough to cause death of fish, does adversely affect growth and well being of fish.
Keywords: *Fish growth, water quality, Catla catla, relative condition factor, Algal bloom.*

Introduction

There are good numbers of studies on seasonal variation in water quality of lakes (Banerjea 1967, Munawar 1970, Boyd 1979, Singh & Rai 1984, Ansari & Prakesh 2000, Sharma and Rathore 2000, Khabade et al. 2002, Datta et al. 2005, Sukamarn & Das 2005). On the other hand there are studies on growth and well being of fish in water bodies (Le'Cren 1951, Jhingran 1952, 1968, Tesch 1968, Doha & Dewan 1967, Botros 1970, Bashirulla & Kader 1970, Siddique 1977, Quadri & Mir 1980, Olatunde 1983, Nwadairo 1985, Rekhow 1987, Prinsloo & Schoobee 1987, Staggis & Otis 1996, Sharma & Sinha 2000, Patgiri et al. 2001, Solanki et al. 2004, Boniamin laskar et al. 2005). However these studies did not investigate whether prevailing conditions were congenial for well being of fish. The merological approach for the studies on water bodies might not be useful in assessing suitability of water bodies for fish culture, whereas holological approach with emphasis on fish growth, water quality, and plankton diversity and density might be useful. Hence, there is a need to investigate variation in fish growth parameters along with physico-chemical and biological water quality parameters, to find out whether variation in growth and well being of fish are influenced by fluctuations in water quality. Studies on these lines are essential to assess suitability of water bodies for fish culture. In the present study we have compared growth co-efficient and relative condition factor of the major carp, *Catla catla* in two

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during different seasons in two perennial lakes to find out whether difference if any in water quality affects growth and relative condition factor.

Materials and methods

The present study was conducted on two perennial rain fed lakes viz. Yennehole lake (YL) (120° 12' 22" N and 760° 31' 12" E 717 mts MSL) and Bilikere lake (BL) (12° 19' 47" N and 76° 27' 45" E 810.46 mts MSL). Both the lakes are being utilized for fish culture since 10 – 15 years. YL is situated in southwest region of Mysore City and spread over about 200 acres and has depth of about 3 – 4 mts. It is mainly used for culture of commercially important major carps. BL has an area of 32.5 acres and depth about 3 to 3.5 mts, which is utilized for irrigation, fish culture and domestic purposes.

The length – weight relationship of the major carp *C. catla*, was studied for two calendar years i.e. January 2002 to December 2003. During the study period length and weight of 15 specimen from each lake were recorded separately at monthly intervals. Later the data were pooled season wise (summer, monsoon and winter) to compute average for each season. The total length and the body weight were recorded immediately after the collection with the help of measuring board and weighing balance. The values of length and weight were determined to the nearest mm and mg respectively. The length- weight relationship was determined using the parabolic equation

(LeCren 1951), W= a L^b (where W= weight of the fish, a= Multiplying constant, b= exponent of length , the growth factor and L= length of fish) for a given season. .

The correlation co-efficient 'r'was calculated by using following formula (Haynes, 1982).

$$r = \Sigma XY - X\,\Sigma Y / \sqrt{[(\Sigma X^2 - X\,\Sigma X)(\Sigma Y^2 - Y\Sigma Y)]}$$

The relative condition factor (Kn) was computed by using formula (Le Cren, 1951),

$K_{n.}= W^o / W^c$, Wherein W^o = Observed weight of the fish, and W^c = Calculated weight of the
fish.

Water samples were collected from three sampling sites at monthly intervals from both lakes. Samples were collected between 08 00 to 10 00. Temperature, pH and DO were recorded on spot using portable kit. Total alkalinity, turbidity, TSS, BOD, hydrogen sulphide, phosphate nitrite and nitrate and ammonia were determined separately for all the samples in the laboratory by employing methods described in standard methods (APHA 1995). Arithmetic mean of each parameter computed considering values of three sampling sites. Monthly mean values were pooled to obtain season wise average.

Water samples for studying of phytoplankton and zooplankton diversity and density were collected simultaneously using nets of mesh size 20 µm and 45µm respectively. One hundred liter of sub surface water was filtered through the nets and organisms were collected in glass bottles tied to the bottom of the net. Zooplankton were immediately transferred to specimen tubes with 4% formalin, whereas phytoplankton to Lugol's solution for later microscopic observation. Plankton counts were made in laboratory using Sedgewick rafter counting cells (Welch 1952). Values were computed and expressed in units/ liter. Phytoplankton were identified following keys of Desikachary

(1959), Gonzalvis (1981) and Prescot,(1982). Zooplankton were identified following description of Edmondson (1959), Battish (1992), and Dhanapathi (2000).

Results

Growth co-efficient and relative condition factor

The growth co-efficient (b) was less than 3 in all the seasons in both the years in YL whereas in BL it was close to 3 or > 3 in all seasons except monsoon, 2002. The correlation coefficient (r) ranged from 0.6004 (summer 2003) to 0.9251 (monsoon 2003) during different seasons of study period (two years) in YL whereas it ranged from 0.8376 (winter 2002) to 0.9248 (monsoon 2003) in BL. The values of correlation co-efficient were statistically significant ($p < 0.05$) for all the seasons and for both the lakes.

The relative condition factor (Kn) was < 1 in all the seasons in two years in YL whereas it was 1 or > 1 in all the seasons during same period in BL.

Table 1. *Length-weight relationship of Catla catla in Yennehole lake (YL) and Bilikere lake (BL) during 2002*

Season & Lake		Number of Fish studied	Growth co-efficient (b)	Calculated 'a'	$W=aL^b$	Correlation co-efficient (r)	Relative condition factor (Kn)
Monsoon	YL	60	2.61561	3.77477	$3.7747L^{2.61561}$	0.90014	0.87776
	BL	60	2.60803	0.12923	$0.12923L^{2.60803}$	0.86684	1.0084
Winter	YL	60	2.10089	4.17332	$4.17332L^{2.10089}$	0.90452	0.9612
	BL	60	3.02897	0.93407	$0.93407L^{3.02897}$	0.8376	1.0539
Summer	YL	60	2.71786	0.09595	$0.09595L^{2.71786}$	0.87046	0.93941
	BL	60	3.20223	0.01601	$0.01601L^{3.20223}$	0.85716	1.0350

Table 2. *Length-weight relationship of Catla catla in Yennehole lake (YL) and Bilikere lake (BL) during 2003*

Season & Lake		Number of Fish studied	Growth co-efficient (b)	Calculated 'a'	$W=aL^b$	Correlation co-efficient (r)	Relative condition factor (Kn)
Monsoon	YL	60	2.24267	0.45181	$0.45181L^{2.24267}$	0.92512	0.86503
	BL	60	3.30474	0.01697	$0.01697L^{3.30474}$	0.9248	1.0177
Winter	YL	60	2.09001	0.67138	$0.67138L^{2.09001}$	0.8742	0.98708
	BL	60	3.34729	0.00932	$0.00932L^{3.34729}$	0.9012	1.0134
Summer	YL	60	1.52285	5.12968	$5.12968L^{1.52285}$	0.60046	0.8576
	BL	60	2.98760	0.04285	$0.04285L^{2.98760}$	0.87426	1.0021

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Physico-chemical water quality parameters

Temperature in both lakes, in both the years of study did not show significant variation amongst different seasons. Further there was no significant variation in water temperature between both the lakes in all the seasons during the study period. The pH showed significant variation in both lakes in 2002, but not in 2003. The pH of BL was significantly lower compared to YL during winter of 2002 and monsoon and summer of 2003. During other seasons of the study period it did not differ significantly. Turbidity did not significantly vary amongst different seasons in YL in both years and in 2003 in BL. However, a significant variation was observed in 2002 in BL. Turbidity was significantly higher in YL compared to BL in all the seasons in both the years.

TSS did not significantly vary in BL in all seasons in both years whereas a seasonal variation was observed during 2003, but not in 2002 in YL. There was no significant difference between TSS of two lakes throughout study period except a significant decrease in BL in monsoon 2003 compared to YL. Total alkalinity did not significantly vary amongst different seasons in both years in YL. However it showed significant seasonal variation in 2002, but not in 2003 in BL. Total alkalinity of BL in winter and summer of both years was significantly lower compared to YL in both years, whereas it did not significantly differ during monsoon of both years.

DO content of YL did not show significant variation amongst different seasons in both years. DO content was significantly lower in winter and summer compared to monsoon in BL during 2002. A similar pattern was seen in 2003, however drop in winter 2003 was not significant compared to monsoon. In both years DO content of BL was significantly lower during winter and summer compared to that of YL whereas it did not differ during monsoon. The BOD did not significantly vary amongst different seasons in both years in YL whereas a significant seasonal variation was observed in 2003 in BL but not in 2002. Excepting monsoon in both years BOD of YL was significantly higher than BL in both years. Hydrogen sulphide content remained unchanged throughout the year in both lakes and it was significantly higher in YL compared to BL in all seasons. Nitrite concentration did not show significant seasonal variation in both years in BL, whereas it showed significant seasonal fluctuation in YL in 2003, but not in 2002. Nitrite concentration of BL was significantly lower in all the seasons compared to YL in both years. Nitrate concentration did not significantly vary amongst different seasons in both lakes in 2002. However in 2003 there was a significant seasonal variation in nitrate concentration in both lakes. The nitrate concentration of YL was significantly higher in all the seasons in both the years compared to BL. Phosphate concentration did not significantly vary amongst different seasons in both lakes in both years, and in all the seasons it was higher in YL compared to BL. In YL ammonia concentration varied significantly amongst different seasons in both years but in BL it did not. During entire study period ammonia concentration was significantly higher in YL compared to BL.

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Table 3. *Seasonal variation in physico-chemical water quality parameters of Yennehole lake (YL) and Belikere lake (BL) during 2002*

	Yennehole Lake			
Parameters	**Monsoon**	**Winter**	**Summer**	**ANOVA F-value**
Temperature (°C)	26.05± 0.71	25.03 ± 1.71	26.37 ± 0.81	0.35 NS
pH	9.01 ± 0.11[a]	9.45± 0.13[b]	9.02± 0.009[a]	5.476 *
Turbidity (NTU)	54.34± 8.07	66.18± 8.62	76.24± 8.67	1.678 NS
TSS	1.26± 0.006	0.67± 0.53	0.60± 0.21	3.293 NS
Total alkalinity	960.37± 60.4	1080.4± 135.7	1165± 110.4	0.926 NS
DO	18.56± 2.87	15.23± 0.18	17.36± 3.57	1.025 NS
BOD	47.14± 12.97	24.71± 1.81	41.01± 12.01	1.277 NS
H_2S	5.29± 0.39	2.58± 023	4.42± 1.38	2.698 NS
Nitrite	0.70± 0.17	0.88± 0.11	0.47± 0.11	2.124 NS
Nitrate	1.0± 0.00	0.94± 0.1	0.73± 0.008	2.544 NS
Phosphate	1.87± 0.18	1.44± 0.16	1.55± 0.1	1.942 NS
Ammonia (µg/L)	286.49± 82.03[a]	171.30± 19.6[b]	235.24± 52.24[a]	8.772 *
	Bilikere Lake			
Temperature (°C)	26.81 ± 1.43	25.34 ± 1.05	26.81±1.43	0.399 NS
pH	9.09± 0.009[a]	8.52± 0.14[b]	8.99± 0.009[a]	24.961 *
Turbidity (NTU)	30.98± 3.09[a]	17.28± 6.34[a,b]	9.32± 2.29[b]	6.536 *
TSS	0.72± 0.003	0.45± 0.34	0.36± 0.008	2.823 NS
Total alkalinity	899.16± 15.62[a]	426.6± 67.16[b]	859.99± 57.84[a]	6.391 *
DO	14.71± 2.33[a]	9.48± 0.76[b]	9.62± 0.94[b]	5.034 *
BOD	37.30± 12.67	14.43± 1.70	14.34± 1.38	3.172 NS
H_2S	1.01± 0.20	0.56± 0.1	0.76± 0.16	1.994 NS
Nitrite	0.004± 0.003	0.007± 0.006	0.0006± 0	0.606 NS
Nitrate	0.49± 0.16	0.53± 0.12	0.39± 0.12	0.304 NS
Phosphate	0.42± 0.25	0.17± 0	0.007± 0	1.311 NS
Ammonia (µg/L)	39.24± 8.04	30.38± 4.24	28.16± 12.08	0.451 NS

Parameters	**Seasons**		
	Monsoon	**Winter**	**Summer**
Temperature	NS	NS	NS
pH	NS	P < 0.05	NS
Turbidity	P < 0.05	P < 0.05	P < 0.05
TSS	NS	NS	NS
Total alkalinity	NS	P < 0.05	P < 0.05
DO	NS	P < 0.05	P < 0.05
BOD	NS	P < 0.05	P < 0.05
Hydrogen sulphide	P < 0.05	P < 0.05	P < 0.05
Nitrite	P < 0.05	P < 0.05	P < 0.05
Nitrate	P < 0.05	P < 0.05	P < 0.05
Phosphate	P < 0.05	P < 0.05	P < 0.05
Ammonia	P < 0.05	P < 0.05	P < 0.05

Note: All parameters other than temp, pH, turbidity and ammonia are mg/L. Mean values of each parameter compared by one way ANOVA followed by Duncan's multiple range test. Values with same superscript letter in different seasons for the given lake (rows) are not significantly different. Whereas those with different superscript letters are significantly (P<0.05) different. * P<0.05.
Comparison of each parameter of YL and BL in each season as judged by Students t- test (significant if P < 0.05)

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Table 4. *Seasonal variation in physico-chemical water quality parameters of two lakes during 2003*

	Yennehole Lake			
Parameters	**Monsoon**	**Winter**	**Summer**	**ANOVA F-value**
Temperature (°C)	26.64± 1.28	25.49± 1.72	26.34± 0.99	0.158 NS
pH	9.14± 0.009	9.29± 0.009	9.35± 0.004	2.481 NS
Turbidity (NTU)	76.33± 9.0	64.88± 7.51	50.77± 14.77	1.400 NS
TSS	0.65± 0.009^{a}	0.70± 0.12^{a}	0.40± 0.004^{b}	5.080 *
Total alkalinity	929.34± 37.13	955.97± 38.17	995.21± 81.48	0.348 NS
DO	12.83± 0.62	15.0± 0.96	10.93± 1.35	3.947 NS
BOD	48.67±8.46	32.49±2.98	44.59±7.11	1.621 NS
H_2S	3.56±0.99	3.02±0.76	3.49±0.72	0.056 NS
Nitrite	0.66±0.19^{a}	1.21±0.12^{b}	0.29±0.009^{a}	10.08 *
Nitrate	0.89±0.008^{a,b}	1.19±0.13^{b}	0.63±0.008^{a}	7.432 *
Phosphate	1.72± 0.22	1.79± 0.22	1.62± 0.007	0.212 NS
Ammonia (µg/L)	195.83±58.74^{c}	82.66±7.33^{a}	133.33±17.78^{b}	24.48 *
	Bilikere Lake			
Temperature (°C)	27.02± 1.29	26.00± 1.06	27.37± 0.34	0.413 NS
pH	8.98± 0.008	8.94± 0.12	8.88± 0.21	0.510 NS
Turbidity (NTU)	33.04± 6.44	20.97± 6.61	15.9± 2.50	2.540 NS
TSS	0.37± 0.004	0.51± 0.12	0.32± 0.007	1.267 NS
Total alkalinity	519.99± 167.89	415.83± 74.44	429.16± 161.65	0.161 NS
DO	12.25± 1.56^{b}	9.93± 0.71^{a,b}	7.24± 0.62^{a}	5.652 *
BOD	37.99±8.81^{b}	16.30±1.88^{a}	17.54±3.20^{a,b}	5.024 *
H_2S	0.70±0.17	0.78±0.15	0.62±0.10	0.387 NS
Nitrite	0.0008±0.0	0.29±0.15	0.0003±0.0	3.544 NS
Nitrate	0.24±0.10^{a}	0.71± 0.11^{b}	0.31±0.005^{a}	7.098 *
Phosphate	0.50± 0.41	0.68± 0.25	0.21± 0.16	0.669 NS
Ammonia (µg/L)	18.90± 4.68	16.46± 5.10	22.58± 6.86	0.300 NS

Parameters	**Seasons**		
	Monsoon	**Winter**	**Summer**
Temperature	NS	NS	NS
pH	P < 0.05	NS	P < 0.05
Turbidity	P < 0.05	P < 0.05	P < 0.05
TSS	P < 0.05	NS	NS
Total alkalinity	NS	P < 0.05	P < 0.05
DO	NS	P < 0.05	P < 0.05
BOD	NS	P < 0.05	P < 0.05
Hydrogen sulphide	P < 0.05	P < 0.05	P < 0.05
Nitrite	P < 0.05	P < 0.05	P < 0.05
Nitrate	P < 0.05	P < 0.05	P < 0.05
Phosphate	P < 0.05	P < 0.05	P < 0.05
Ammonia	P < 0.05	P < 0.05	P < 0.05

Note: All parameters other than temperature, pH, turbidity and ammonia are mg/L. Mean values of each parameter compared by one way ANOVA followed by Duncan's multiple range test. Values with same superscript letter in different seasons for the given lake (rows) are significantly different. Whereas those with different superscript letters are significantly (P<0.05) different. * P<0.05. Comparison of each parameter of YL and BL in each season as judged by Students t- test (significant if P < 0.05)

Diversity and density of plankton study

Forty species of phytoplankton and 24 species of zooplankton were found in YL whereas 68 species of phytoplankton and 42 species of zooplankton were found in BL. Phytoplankton belonged to five different classes *viz.* cyanophyceae, chlorophyceae, bacillariophyceae, euglenophyceae and desmidiaceae. Zooplabnkton belonged to orders rotifera, copepoda, cladocera and ostracoda.

Phytoplankton population of YL was dominated by cyanophycean members in all the seasons of both years. Summer of 2002 recorded a significant increase in cyanophycean population compared to other two seasons. Same pattern was found in 2003 but the increase was not significant. Cyanophyceae in YL was represented by 10-12 species in different seasons of 2002 and 2003. *Microcystis arruginosa* kutz; was most dominating species among them and it was followed by several species belonging to genera, *Oscillatoria, Anabaena and Nostoc*. They formed a thin bloom on the water surface almost all the seasons of the study period. In BL cyanophycean density showed significant seasonal variation in 2003 but not in 2002. Cynophyte density in BL was significantly lower compared to YL in all the seasons of both the years. Chlorophyceae was third dominant group in YL and their density did not show significant seasonal variation in both the years. Chlorophytes were represented by 6-9 different species during study period. Phytoplankton of BL was dominated by chlorophytes, represented by 16-24 species during different seasons and their density showed significant seasonal variation in 2002, with an increase in density in summer. Similar pattern was found in 2003. Chlorophyceae density of BL did not show significant difference with that of YL in all the seasons in both years, except a significant decrease in monsoon 2002.

Bacillariophyceae were second dominant class in YL and their density did not show significant seasonal variation in both years. Bacillariophytes in YL were represented by 8-12 different species in different seasons of the study period. In BL bacillariophytes showed significant seasonal variation in both years. However, the pattern of variation was not similar in consecutive years. Density of bacillariophytes in YL and BL did not significantly differ in all the seasons, except a significant decrease in BL in monsoon 2002. Density of euglenophytes in YL did not show any significant seasonal variation in both the years and it was represented by 8-9 different species in different seasons of study period. In BL euglenophytes were represented by 6-7 species in different seasons of both the years and showed significant seasonal variation in their density in both years. However pattern of variation was not similar in consecutive years. Euglenophytes density of BL was lower than YL in all the seasons.

Desmids were conspicuous by their absence in YL in both the years whereas in BL desmids population was quite considerable in all the seasons of both the years and showed significant seasonal variation in both years, with high density in monsoon. They were represented by 8 -11 species in different seasons of the study period.

Rotifer density in both lakes showed significant seasonal variation with high density in summer compared to other seasons. In all the seasons during two-year period rotifer density was significantly lower in BL compared to YL. However, rotifers were represented by more number of species in BL than YL. Copepoda in YL were represented by 3-4 species their density showed significant seasonal fluctuation in 2002, but not in 2003. In BL copepod density was significantly increased in winter 2002.

Copepodes were represented by 5-7 species in different seasons in BL and their density in BL during all the seasons of 2002 and in winter of 2003 was significantly lower compared to YL.

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Table 5. *Seasonal variation in plankton density in Yennehole lake and Bilikere lake, 2002*

Plankton / Lake		Monsoon	Winter	Summer	ANOVA F-value
Cyanophyceae	YL	29050±4031.23[a] (12)	34025±4219.86[a,b] (12)	40870±1265.66[b] (10)	5.963 (P <0.05)
	BL	6425 ±782.49 (09)	9300±1149.63 (07)	9750±1354.31 (08)	2.591 (NS)
Chlorophyceae	YL	9500±1666.33 (09)	8000±804.15 (08)	9250±717.05 (08)	0.492 (NS)
	BL	6725±601.90[a] (13)	9800±963.50[a,b] (16)	12100±1948.07[b] (16)	5.290 (P <0.05)
Bacillariophyceae	YL	10600±1292.92 (09)	9050±494.13 (11)	9300±1068.48 (12)	0.679 (NS)
	BL	6200±302.76[a] (10)	11200±721.11[b] (11)	8740±186.84[a,b] (10)	6.018 (P <0.05)
Euglenophyceae	YL	9400±355.90 (08)	10600±948.68 (09)	8200±989.10 (08)	2.155 (NS)
	BL	7175±661.28[b] (06)	4200±452.76[a,b] (07)	3550±545.43[a] (07)	11.925 (P <0.05)
Desmids	YL	NIL	NIL	NIL	NIL
	BL	7900±511.53[b]	3800±374.16[a]	4500±254.95[a]	30.921 (P <0.05)
Rotifers	YL	643±32.54[a] (10)	613±36.77[a] (12)	858±86.43[b] (11)	5.421 (P < 0.05)
	BL	218±26.77[a] (17)	138±15.87[a] (15)	422±68.43[b] (19)	11.382 (P <0.05)
Copepods	YL	580±67.56[a] (04)	636±67.42[a] (04)	298±14.86[b] (04)	13.034 (P < 0.05)
	BL	171±32.60[a] (07)	292±7.39[b] (06)	168±12.49[a] (07)	12.999 (P <0.05)
Cladocera	YL	182±16.87 (04)	210±11.80 (04)	146±12.86 (03)	2.641 (NS)
	BL	122±20.89[a] (05)	248±23.62[b] (05)	108±20.86[a] (06)	12.496 (P < 0.05)
Ostracods	YL	74±12.36[a] (04)	77±18.96[a] (03)	38±2.86[b] (03)	5.665 (P<0.05)
	BL	57±11.56[a] (06)	80±12.94[b] (06)	56±3.16[a] (04)	11.600 (P< 0.05)

Plankton	Seasons		
	Monsoon	Winter	Summer
Cyanophyceae	P < 0.05	P < 0.05	P < 0.05
Chlorophyceae	P < 0.05	NS	NS
Bacillariophyceae	P < 0.05	NS	NS
Euglenophyceae	NS	P < 0.05	P < 0.05
Desmids	il	Nil	Nil
Rotifers	P < 0.05	P < 0.05	P < 0.05
Copepods	P < 0.05	P < 0.05	P < 0.05
Cladocera	NS	NS	NS
Ostracods	NS	NS	NS

Table 6. *Seasonal variation in plankton density in Yennehole lake and Bilikere lake, 2003*

Plankton (units/lits)		Monsoon	Winter	Summer	ANOVA F-value
Cyanophyceae	YL	31875±4248.79 (13)	34475±4819.98 (12)	45100±6258.06 (10)	2.062 (NS)
	BL	8100±866.02^{a} (11)	14250±1374.46^{b} (09)	11100±1707.82^{a,b} (11)	5.107 (P<0.05)
Chlorophyceae	YL	9800±904.23 (06)	9500±665.83 (09)	10100±854.40 (08)	0.136 (NS)
	BL	9100±782.09^{a} (16)	7500±823.60^{a,b} (16)	11550±1060.26^{b} (16)	5.171 (P<0.05)
Bacillariophyceae	YL	8000±580.22 (09)	10550±1447.12 (10)	9125±604.66 (08)	1.752 (NS)
	BL	7900±491.59^{a} (10)	10600±960.03^{b} (12)	13800±875.59^{c} (13)	13.119 (P <0.05)
Euglenophyceae	YL	8100±1191.63 (08)	8050±375.27 (09)	10425 ±1326.88 (08)	1.663 (NS)
	BL	6700±467.26^{a} (07)	2850±370.80^{b} (06)	5325±525.0^{a} (07)	18.064 (P <0.05)
Desmids	YL	NIL	NIL	NIL	NIL
	BL	7425±306.52^{c} (09)	4650±233.63^{b} (09)	3600±285.77^{a} (08)	50.897 (P <0.05)
Rotifers	YL	495±56.93^{a} (12)	561±70.28^{a} (12)	947±145.98^{b} (10)	6.087 (P < 0.05)
	BL	172±24.98^{a} (18)	228±32.01^{a} (17)	354±28.69^{b} (20)	10.315 (P <0.05)
Copepods	YL	324±67.23^{a} (03)	810±130.36^{b} (04)	270±13.39^{a} (04)	12.232 (P <0.05)
	BL	236±57.89 (07)	331±30.88 (06)	198±38.75 (05)	2.499 (NS)
Cladocera	YL	172±32.12^{a} (04)	168±16.46^{a} (03)	116±12.86^{a} (04)	6.092 (P < 0.05)
	BL	125±20.69^{a} (05)	164±23.20^{a} (07)	224±18.38^{b} (07)	9.326 (P <0.05)
Ostracods	YL	38±6.42 (04)	46±8.02 (04)	28±2.06 (03)	1.891 (NS)
	BL	10±3.5^{b} (04)	46±4.08^{a} (06)	58±8.75^{a} (04)	19.358 (P <0.05)

Plankton	Seasons		
	Monsoon	**Winter**	**Summer**
Cyanophyceae	P < 0.05	P < 0.05	P < 0.05
Chlorophyceae	NS	NS	NS
Bacillariophyceae	NS	NS	NS
Euglenophyceae	NS	P < 0.05	NS
Desmids	Nil	Nil	Nil
Rotifers	P < 0.05	P < 0.05	P < 0.05
Copepods	NS	P < 0.05	P < 0.05
Cladocera	NS	P < 0.05	NS
Ostracods	P < 0.05	NS	NS

Cladoceran density did not show significant seasonal variation in YL in both the years whereas they showed significant variation in their density in BL in both years. There was no significant difference between cladodoceran population of YL and BL in all the seasons of the study period.

The seasonal variation in density of ostracods in 2002 was significant in both lakes whereas in 2003, it was significant only in BL but not in YL.

Discussion

In the present study seasonal variation in different physico-chemical parameters, which are known to influence well being of fish and growth of plankton have been studied, to find out whether differences in these parameters in two lakes is accompanied by difference in growth co- efficient and relative condition factor of a major carp *C. catla.*

In the present study water temperature of YL ranged from 25.03°C to 26.64°C in both the years where as that of BL was 25.34°C to 27.37°C. Since a range of 28-32°C in tropical waters (IFAS: Insttitute of food and agricultural sciences, University of Florida,Circular-1051, Jinghran ,1968) is congenial for optimal growth of fish, both the lakes under study showed temperature closer to the lower limits of the optimum range. Similarly, the DO content of both the lakes during entire study period was conducive for fish growth as it was well above the minimum required amount (i.e. 5mg/lit., Alabaster & Lloid, 1980). Since higher levels of total suspended solids clog the fish gills, their concentration less than 25mg/lit is preferred (Maitland, 1990). In our study TSS level was well within the range in both lakes. However, other physico-chemical parameters showed significant difference between two lakes and some of them were in undesirable level in YL compared to BL. For instance, low turbidity (20-30 NTU) is desirable for fish culture (Zweig, 1989) as high level turbidity affects the photosynthetic process and there by the potential yield of the lake (Sukumaran & Das 2005). In BL turbidity level was within the desirable range (9.3 NTU – 33.04 NTU) whereas that in YL was (50.77NTU – 76.33NTU) higher than desired range. Similarly higher alkalinity (pH >9) in water bodies is unsuitable for good fish production (Boyd 1979). The water pH in YL was always higher than 9 whereas in BL it was less than 9 in majority of the seasons. Likewise total alkalinity in YL (929.34 mg/lit to 1016.5 mg/lit) was remarkably higher than optimal range (100 to 400 mg/lit, Schroeder, 1980) for fish culture. Whereas in BL, excepting monsoon it was within desired range of alkalinity preferred for fish culture.

BOD indicates the presence of organic load in a water body and waters having BOD more than 35 to 45 mg/lit are not good for fish culture (Pande & Sharma 1999). In the present study BOD level in YL exceeded the preferred range in all the seasons except in winter in contrast to BL wherein it was in preferred range in all seasons except monsoon.

Phosphate is a nutrient which causes rich phytoplankton crop (Moss, 1993). An optimum level 0.1 to 0.2 mg/lit phosphate (Sreenivasan, 1965) is needed for growth of plankton. In our study, in YL the phosphate concentration was several folds higher than optimal level (0.1 to 0.2 mg/lit, Sreenivasan, 1965) needed to support phytoplankton growth. Whereas in BL it was within desirable range except in monsoon.

Nitrite could be hazardous to fish if it exceeds the permissible range (Train & Russel 1979) which is 0.015 mg/lit for salmonids (Iwama et al. 2000) and generally 0.1mg/lit considered tolerable range in tropics (Hart & Reynolds, 2002). In the present study YL exceeded the tolerance limit whereas in BL it was very well with in the desirable range throughout the year. Minimum level of nitrate required for the lake to be productive is 0.1mg/lit (Srinivasan 1965, Hart & Reynolds, 2002). In the present study nitrate content although exceeded the optimal level in both the lakes, the concentration of nitrate was far higher in YL than BL. The excessive level of nutrients in YL was reflected in the presence of algal bloom during most part of the study period.

Unionized ammonia in the range of 0.02 – 0.2mg/lit is toxic (Alabaster & Lloyd, 1980., Joseph et al. *1993*) to fishes as excessive ammonia in water tends to block O_2 transfer from gills to the blood (Smart, 1978). In the present study ammonia content in YL was not only significantly higher than BL but was also in toxic level.

Hydrogen sulphide in water bodies is another indication of pollution (Oslen & Sommerfeld 1977). In the present study H_2S is the only parameter, which was in undesirable range in both the lakes. It ranged from 2.58 mg/lit to 5.29 mg/lit in YL and from 0.56 mg/lit to 1.01 mg/lit in BL. High levels of pH, total alkalinity, turbidity, BOD, H2S, phosphate and nitrite were reported in number of studies in different lakes in India and outside, to cite a few, Hutchinson 1957, Verma 1967, Banergia 1967, Saxena & Adoni 1973, Ayyappan & Gupta 1981, Yousuf et al. 1986, Kaur et al. 2000, Ragavendra & Hosmani 2002. However these studies did not focus on the fact that whether these conditions interfered with growth and well being of fish in these water bodies. The isometric growth of fish under optimum conditions follows length-weight relationship, wherein weight is cube of length.(cube rule , Le Cren, 1951). In the length weight relationship equation ($W=aL^b$), b is the growth co-efficient and its value is 3 (Allen, 1938) under optimal conditions. Hile (1936) and Martin (1949) opined that value of b usually lies between 2.5 and 4. Hence, in the study of length weight relationship, value of b because less than 2.5 can be considered as subnormal growth of fish in that given lake. Further the relative condition factor (Kn) is an expression used to asses the condition of fish, and Kn value 1 or more than 1 is considered as well being of fish. The present study, which compares these parameters of *C. catla* in two lakes, for two calendar years, reveals a few interesting facts. The growth coefficient (b) was 3 or close to 3 in majority of seasons, accompanied by Kn value 1 are more than 1 in BL, where as it was less than 3 accompanied by Kn value less than 1 in all the seasons in YL. These observations clearly indicate better growth and health (well being) of *C. catla* in BL than in YL. Although several earlier studies on fish growth reveled sub optimal growth of fish they did not provide evidence of any causative factor. In the present study, the sub optimal growth of *C. catla* in YL was accompanied by high pH, turbidity, total alkalinity, BOD, nitrate, nitrite, phosphate, hydrogen sulphide and ammonia which were beyond normal range for fish culture in contrast to lower values of these parameters accompanied by normal growth of *C. catla* in BL. Higher levels of these physico-chemical factors directly or indirectly interfere with fish physiology and affect their growth. For instance high turbidity (Zweig, 1989) reduces photosynthetic zone resulting in night time decline of DO and higher pH (Boyd, 1979) influences the blood pH and causes alkalosis; damages skin, gills and eyes; and increases mucus production. Similarly, oxygen consumption of fish is affected by high nitrite, nitrate and ammonia (Tilak et al. 2005) as nitrate in addition high ammonia interferes with oxygen transport from gills to blood (Smart, 1978.,Lewis & Morris, 1986., Datta et al. 2005) and damages gills. Sub-optimal levels of unionized ammonia (0.1 – 0.42 mg/lit) causes significant variation in condition factor (Datta et al. 2005). Likewise higher than tolerable level of hydrogendulphide might cause death to the fishes or at the very least stress (Barthelmes & Bramick 2003). The combined effect of all these physico-chemical factors might induce stress response as suggested by Iwama (2000). It is well known that stress adversely affects growth of animals. Hence, the sub optimal growth of *C. catla* as indicated by deviation from cube rule and lower Kn values in YL are due to prevailing physico-chemical conditions in YL. This view is further supported by the fact that the above parameters which are in normal range in BL in which not only growth co-efficient of *C.catla* obeyed the cube rule but also Kn values indicated well being of fish.

The difference in physico-chemical characteristic in two study lakes was also reflected in plankton density and diversity; indicating water contamination in YL. Although phytoplankton being producers play a key role in aquatic food chain, higher nutrient levels cause their bloom, which will be detrimental to fish by various effects. Nutrient enrichment resulting in algal bloom is indicated by excessive growth of certain algal s genera ; *Microcystis , Anabaena, Oscillatoria, Scenedesmus, Pediastrum, Fragellaria etc*. (Palmer, 1980., Bush & Welch, 1972). In the present study YL showed algal bloom throughout the year and was dominated by cyanophytes, especially *Microcysties , Oscilotoria, Anabina* etc and bacillariophytes such as *Navicula, Nitzschia, Synedra* etc, which indicate nutrient load and sewage pollution (Palmer,1980). This view is also supported by the presence high density of rotifers viz. *Brachionus angularis, B. quadricormis, Keratella cochlearis, Felinia longiseta, Polyarthra vulgaris* and *Conochilus dassaurius*, which are also an indicator of high nutrient load (Sharma et al. 1999., Bahura et al. 1993) . In contrast in BL, low nutrient levels compared to YL was accompanied by the presence of desmids, high density of chlorophyceae which grow better in waters with low organic matter and high DO (Goldman & Home, 1983). Cyanophytes dominated by *M. aeruginosa* are found to produce two toxins viz; hepatotoxin , microcystin and a neurotoxin, anatoxin and adversely effect the well being of the fish (Ballot et al. 2003). Cyanophycean bloom also causes “off flavor” either by producing a substance called MIB (Methyl isoborneal) or by the decomposition process of their own counterparts (Martin, et al; 1994). In our study we observed bloom and off flavor in YL quite often . In addition, plankton diversity was more in BL than in YL. Put together these biological parameters indicate better conditions in BL than in YL. Hence the study by comparing growth

co-efficient and relative condition factor of same species in two water bodies which difffer in physico-chemical properties, first time provides an evidence for the fact that water quality parameters in undesirable range in natural water bodies interfere with growth and well being of fish . It is to be noted that though the conditions in YL were never severe enough to cause fish deaths, they interfered with growth and well being of *C.catla.* Hence such studies will be useful in assessing the suitability of ponds for fish culture.

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