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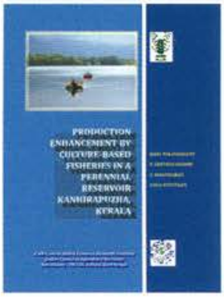

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FOREWORD

Large expansions of 1.5 million hectares of small reservoirs in India hold enormous potential for the intensification of aquaculture practices to enhance the productivity per unit area. Small reservoirs, both perennial and seasonal, in Asian countries are intensively exploited for fish production by active scientific management and enhancement where the yield is strongly related to trophic status of the water body and stocking of seed. In India also fish production from small reservoirs has substantially increased from the national average of 50 kg/ha to manifold through intervention in certain hydrological parameters to improve the trophic status of the reservoir or suitable culture management strategies. Culture-based fisheries in small reservoirs is a successful aquacultural practice in vogue in many parts of the world and in India also for enhancement of fish production. Kanhirapuzha reservoir, situated in Palakkad district of Kerala, was selected for the implementation of culture-based fisheries activities by CIFRI centre, Kochi. It undertook an intensive investigation during 2007 to 2011 on ecology and fisheries of Kanhirapuzha reservoir and evolved suitable scientific management measures with ecosystem approach. I believe this document would help the reservoir fisheries managers of this region to formulate comprehensive culture-based fisheries strategies to raise total fish production from the resources.

July, 2015

A. P. Sharma
Director,
CIFRI

CONTENTS

PRODUCTION ENHANCEMENT BY CULTURE-BASED FISHERIES IN A PERENNIAL RESERVOIR IN KERALA

1. Introduction

There are about 60 000 reservoirs worldwide with a total volume exceeding 10 million m^3 and covering 400 000 km^2. Culture-based fisheries are effective means to increase productivity from these inland waters with adequate attention to carrying capacity and maintenance of environmental quality (FAO, 2014). Nevertheless, reservoir fish production has been treated as a by-product giving it less importance as a fish production system. Kanhirapuzha reservoir located in the tropical west eastern mountainous highlands of Kerala receives a bountiful average annual rainfall of 1000-1500 mm, mainly by southwest monsoon. This reservoir was constructed in 1980 in the Bharathapuzha river basin for the sole purpose of irrigating the down lying agricultural lands in Palakkad district and receives water from two rivers, Palakayam and Irumbagasolai. This reservoir has highly undulated basin with crusts and troughs even in the transitional zone, where the water level varied from 5.4 m to 24 m at full reservoir level. There are several land masses seen with vegetation in the middle of the reservoir.

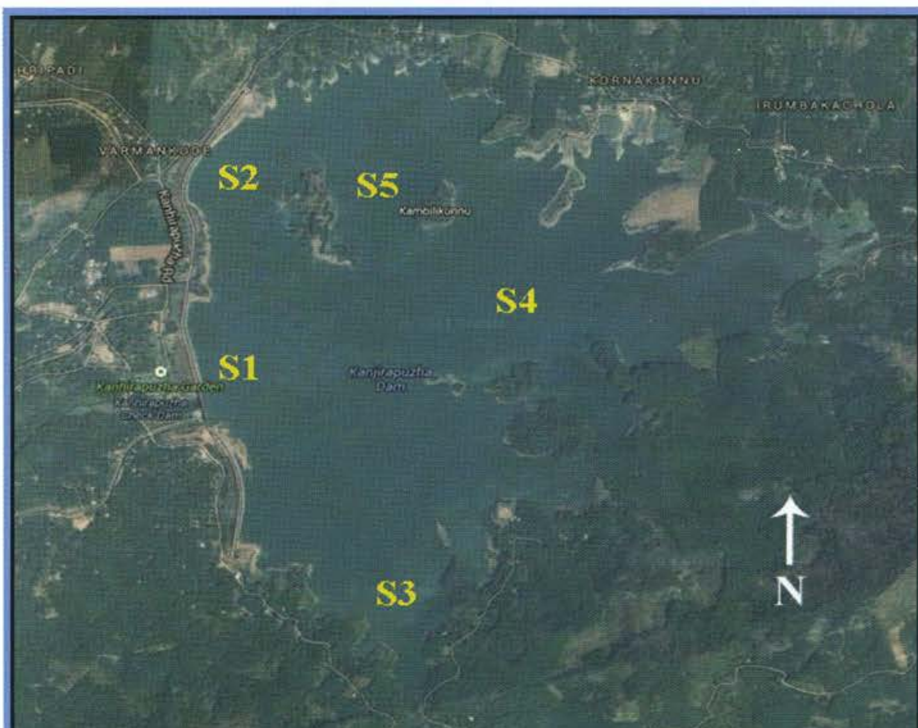

Fig. 1. Satellite image of the reservoir (10 °59'8"N, 76°32'18"E)
S1-S5 are sampling sites

Fig. 2. A wide view of the reservoir

2. Morphology

Kanhirapuzha reservoir with a total area of 515 ha is in the category of small reservoirs (<1000ha) as per the records of the Government of India (Sugunan, 1995).

Fig. 3. A view of the Dam

Its storage capacity is 70.82 mm^3 draining water from 70 square kilometre catchment area spreading in the eastern slope of Western Ghats. This is a perennial reservoir storing water round the year and the release of water even during summer does not decrease the water level drastically.

Reservoirs receive nutrient input from the allochthonous sources, which often determine the water quality, nutrient regime and the basic production potential. Particulate matter originating from within and the surrounding landscape of the stream is an important basal resource to fluvial food webs. The major determinant of reservoir productivity, mean depth of this reservoir is 13.75 m indicating it as moderate deep basin in which bottom region do not lie in the euphotic zone thus showing less productivity. Based on rainfall the seasons of this region can be broadly classified as rainy (June-November) and dry (December - May). The morphoedaphic index (MEI) is most widely used index of potential fish production in reservoirs. This is a metric expression derived by dividing lake's total dissolved solids (mg/l) or its conductivity by its mean depth in meters. Estimation of potential fish production made through MEI can be used for calculating the stocking densities of fish fingerlings in inland reservoirs (Welcomme, 1976). The morphological features of the reservoir are given in Table 1.

Table 1. Morphological features of the reservoir

	DETAILS	
1.	Year of construction	1980
2.	River basin	Bharathapuzha
3.	Volume	70.82 mm^3
4.	Area at FRL	515 ha
5.	Average area	452 ha
6.	Allochthonous input (C/A ratio)	13.59
7.	Volume development index	1.7
8.	Morpho-edaphic index	3.15
9.	Maximum depth	23.7 m
10.	Mean depth	13.75 m
11.	Catchment area	70 km^2
12.	Type of construction	Masonry
13.	Annual rainfall	1000-1500 mm
14.	Annual mean inflow	11.1 m^3/sec
15.	Annual mean outflow	5.0 m^3/sec
16.	In-flowing rivers	Irumbagasolai and Palakayam

3. Sampling procedure

The morphological data was collected from the Irrigation Department, Government of Kerala. The fisheries data were obtained from the Office of the Deputy Director of Fisheries, Palakkad region. For limnological and biological studies, pertinent samples were collected monthly from July 2007 to June 2009 except for few months (June & October 2008) when wind in reservoir was too strong, combined with flash flood. Sampling and analysis of water, soil, biotic communities and primary production were carried out following standard methods (APHA, 1980; Bose, 1998). Water and plankton samples were collected every month for 2007- 2009 spatially at five sites, lentic (site-S1), confined (site-S2), lotic (site-S3),intermediate(site-S4) and between hillocks (site-S5) (Figure 1) and at surface,1m, 2m, middle and bottom of the reservoir.

4. Habitat Characteristics

4.1 Water chemistry and nutrients

The physico-chemical characteristics of the reservoir water play vital role in the productivity of the system. The important physico-chemical features of Kanhirapuzha reservoir are presented in Table 2. Significant variations in these parameters were not observed between months or seasons and they largely depicted the oligotrophic nature of the reservoir.

Temperature:

Temperature of the reservoir water is of primary importance since it regulates biotic growth rates and life stages and defines fishery habitat. It leads to speeding up of the chemical reactions in water. The average surface water temperature of the reservoir varied widely from 25°C during the monsoon season (rainy) to 30.5°C in the summer season (dry). But in certain months, September 2008 at S1 and S4 and February and March 2009 at S1, the maximum temperature difference of 3.5- 4.0°C was observed between the epilimnetic and hypolimnetic layer.

Transparency:

The intensity of the light penetrating through water media is known as transparency. Turbidity is a measure of the cloudiness or murkiness of water due to suspended particles and can be caused by organic particles, such as decomposed plant and animal matter, or living biological organisms (algae), inorganic particles (silt, clay and natural chemical compounds like calcium carbonate). Surface turbidity occurs due to heavy rain, flooding and monsoon runoff landslides. The transparency of Kanhirapuzha reservoir recorded a low of 135.3cm during summer (May) and was higher 251.3 cm (October) following the monsoon season during the entire study period. The transparency level explains the heavy monsoon influx has not lowered the secchi depth because the water content is less turbid and clear.

Dissolved oxygen:

Dissolved oxygen (DO) content in the water reflecting the physical and biological process prevailing in the reservoir was high and conducive (5.1 to 9.0 mgL^{-1}) at surface throughout the study due to the wind activated turbulence. A state of anoxic condition was also observed during the study period as the oxygen level went to a low of 0.6 to 3.2 mgL^{-1}in the middle layers of site S1, S2and S5 during May and June 2009 and nil to 1.6 mgL^{-1} during the other months. But no signs of fish mortality were observed at that time. Biological oxygen demand was also measured for 5 days and it has not shown any significant difference indicating the scant presence of organic substances.

pH:

pH, the measure of the intensity of acidity or alkalinity rising by photosynthesis and declining by respiration is an essential indicator of reservoir productivity. Generally peninsular reservoirs record alkaline property by the presence of carbonates. But Kanhirapuzha probably receives humic acid from the rainfed forest, registered acidic to neutral pH (6.2 -7.8) which is the common characteristic of reservoirs of Kerala. A low pH of 5.7 was also recorded in the late South-West monsoon season, in September 2007.

Free carbon-dioxide:

Free carbon dioxide is essential for synthesis of carbohydrate through photosynthetic activities and it increased as the depth increased. During the period of study the free carbon-dioxide values ranged from 0.4 to 5.1 mgL^{-1}.

Total alkalinity:

Alkalinity of the water is its capacity to neutralize a strong acid and is characterized by the presence of all hydroxyl ions capable of combining with hydrogen ion. It also determines the productivity of the reservoir. The total alkalinity in the range of > 90.0, 40-90 and < 40 $mgL^{-1}$are estimated to be high, medium and low productive, respectively (Sugunan, 1995). Accordingly, the epilimnetic total alkalinity values registered in this reservoir (17.3 to 35.6 mgL^{-1}) indicate that the reservoir is less productive.

Specific conductivity:

Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. The reservoir water exhibited an average electrical conductivity of 45.1mhos cm^{-1} and seasonal fluctuations are absent probably due to the absence of charged ions in allochthonous input.

Hardness:

Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. The hardness of the reservoir on an average was low (19.4 mgL^{-1}).

Calcium and Magnesium:

Calcium is one of the most abundant substances of the natural waters whereas the concentration of magnesium is lower than the calcium. Both are leached from the rocks. Magnesium is required by the flora to build its chlorophyll and for the growth of algae. The depletion of magnesium acts as limiting factor for the growth of phytoplankton and it rauged from 2.45 to 107.0 mgL^{-1} (Goel *et al.*,1986; Khatavkar *et al.*, 1990). Concentration of both calcium (2.1 to 5.8 mgL^{-1}) and magnesium (1.7 to 9.3 mgL^{-1}) in the water samples registered lower values indicating the low productive status of the reservoir and contributing poor supplement for phytoplankton growth.

Trophic State Index:

Trophic state is defined as the total weight of living biological material in a water body at a specific location and time. It is used to classify the nature of the waterbodies as oligotrophic, mesotrophic and eutrophic. The Carlsson's Trophic State Index (TSI) value based on secchi depth (27.28) and phosphorous (44.67) reiterated that Kanhirapuzha reservoir is a classic oligotrophy with clear water, saturated with oxygen round the year in the hypolimnetic zone. Oligotrophic water bodies are characterised by low productivity, low nutrient content, low algal production and clear water.

Nutrient contents

Phosphorous:

The rocks in which most of the phosphorus is bound are generally insoluble in water, and hence the phosphorus content of natural freshwaters is low and biological growth is limited due to this fact. Phosphorus is considered an important element for the growth of plankton and mostly it is in inorganic forms in natural waters. Since, Kanhirapuzha reservoir is devoid of any pollution the phosphorus content is trivial (0 to 0.03 mgL^{-1}) thus indicating that the inflow to the reservoir is from non-polluting sources.

Nitrate:

The most important source of the nitrate is biological oxidation of organic nitrogenous substances. Run-off from agricultural fields is also high in nitrate. Kanhirapuzha reservoir located at the foothills of Western Ghats would naturally record low nitrate values (traces to 0.2 mgL^{-1}), the source of water being pure and not much contaminated.

Silicate:

The next most abundant element in the earth after oxygen is silicon but it occurs in

Table 2. Physico-chemical characteristics of water in Kanhirapuzha reservoir

Period	A.T.	W.T	Trans	pH	Cond	D.O.	CO_2	T.A	C.A.	BA	Ca	Mg	Hardness	PO_4	Sio_3	NO_3
	(°C)	(°C)	(cm)	(units)	(µmhos cm^{-1})	(mgL^{-1})										
Jul-07	27.8	25.7	212.0	7.8	42.6	8.3	1.8	24.5	2.7	21.8	2.5	2.6	13.8	0.03	0.0	0.05
Aug-07	27.6	26.7	239.5	7.0	43.1	7.5	2.3	25.0	2.6	22.4	2.3	3.1	15.2	0.01	31.4	0.05
Sep-07	28.2	26.4	183.8	6.7	44.5	6.3	1.9	24.5	3.3	21.2	2.8	1.8	10.2	0.01	35.5	0.03
Oct 07	27.4	26.6	192.5	6.7	56.1	7.1	2.0	25.2	3.9	21.3	2.9	2.0	11.2	0.02	27.5	0.02
Nov 07	29.2	27.5	251.3	6.8	47.2	7.0	2.3	26.0	6.5	19.5	2.6	1.9	10.4	0.01	22.2	0.02
Dec 07	27.9	25.3	154.5	6.6	47.4	6.2	2.2	27.2	1.8	25.4	2.1	2.3	11.9	0.01	11.7	0.01
Jan 08	28.5	26.4	180.0	7.5	44.5	7.4	1.0	25.7	0.9	24.8	2.6	2.6	11.4	0.03	T	T
Feb 08	30.5	29.1	191.8	6.8	41.7	7.8	2.8	28.1	2.4	25.7	2.4	9.3	13.6	0.02	T	T
Mar 08	30.4	28.3	195.2	6.7	49.6	7.6	1.4	31.5	3.7	27.8	2.2	1.9	12.5	0.00	T	T
Apr 08	30.3	28.7	174.6	7.1	44.1	6.0	0.6	33.8	4.5	29.3	3.4	1.7	15.8	0.02	T	T
May-08	29.5	28.1	181.2	7.1	45.1	6.3	0.9	34.5	4.4	23.0	5.8	4.6	33.3	0.02	T	T
Jul 08	25.0	26.9	168.8	7.7	44.3	7.1	5.1	26.9	3.6	23.3	3.0	3.6	28.5	0.00	T	T
Aug 08	27.5	26.0	183.5	7.1	44.8	6.5	2.3	28.3	2.3	25.6	2.5	1.7	16.7	0.01	T	T
Sep 08	28.0	30.1	177.5	7.6	42.1	6.3	0.4	32.0	1.9	30.1	4.6	2.9	15.5	0.02	T	T
Nov 08	25.7	27.2	189.2	0.0	41.0	6.2	1.2	31.4	2.8	27.1	2.9	2.8	24.7	0.00	T	T
Dec 08	26.3	26.9	201.3	7.3	42.1	6.6	0.8	35.6	2.5	22.3	2.7	3.6	22.9	0.00	T	T
Jan 09	27.1	25.2	146.3	6.9	40.9	9.1	0.7	33.5	2.8	30.7	4.1	3.5	24.6	0.02	37.0	0.02
Feb 09	28.3	29.9	171.4	6.9	43.3	8.9	3.5	44.3	1.6	42.7	4.7	3.6	26.7	0.03	15.3	0.04
Mar-09	29.3	30.7	137.0	6.4	44.1	8.7	1.4	17.3	2.0	14.8	4.5	3.6	26.1	0.02	17.7	0.01
Apr 09	29.5	30.2	131.5	6.4	47.6	7.4	1.2	16.9	1.7	15.2	4.2	4.1	27.7	0.02	16.2	0.01
May 09	28.9	29.2	135.3	6.2	50.4	5.0	1.8	21.2	0.0	0.0	5.0	3.7	28.1	0.02	35.3	0.21
Jun 09	27.9	27.6	135.4	6.9	45.5	6.5	1.0	20.0	0.0	0.0	4.7	3.6	27.0	0.01	25.2	0.08

T- Traces

meagre quantities in Kanhirapuzha water. The solubility of silica has been found to be more at high pH or high temperature. Silicate is the core component of bacillariophyceae. The value of silica in this reservoir ranged from traces to 37.0 mgL^{-1}.

Thermal and oxygen stratification

The thermal and oxygen stratification of a waterbody refers to a change in the temperature or oxygen at different depths in it. The sudden decline in values refers to the productivity status occurring mostly in the middle layer of water bodies. They are referred as oxycline and thermocline which were absent during study period in either of the transitional or lacustrine zone. During April 2008 anoxic conditions (0.08 ppm) were observed at the bottom of station 2 where the depth was 16 m. Thermal or oxygen stratification could not be observed in 2008 but a distinct oxycline was observed in Station S1, (the Lentic zone near the sluice) and station S5 (the protected zones in between the two small hillocks) during April, May, June 2009. It was probably due to the non-mixing of water as there was no water flux during this period, hence the oxycline formed was undisturbed. During these three months, the water was anoxic below 7.0 m depth.

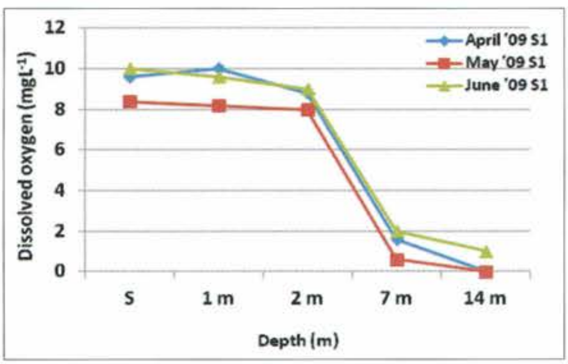

Fig. 4. Occurrence of oxycline

4.2 Sediment characteristics

The basin of this reservoir is largely covered by laterite stone beds with intermittent alluvial soil. Soil pH was acidic ranging from 5.01 to 5.84. Electrical conductivity registered from the low of 32.2 µmhos/cm in February 2009 to the maximum of 70.4 µmhos/cm in June 2009. Electrical conductivity of the soil was comparatively lower in summer season than that of rainy season (June – November, 2007) where the maximum value recorded was 158.8 µmhos/cm. This could be attributed to the marginal input of allochthonous sources during rainy season. The average available phosphorus values ranged from 0.12 (S3) to 1.08 mg/100 g soil in S5. The vast variation in the phosphorus content in the different sites may be due to the nutrient flow affected by hydrodynamics at the reservoir. The percentage of organic carbon content in the soil recorded more than 2.3 during dry season which may be due to pooling of alluvial soil scattered at the bottom basin of the reservoir.

4.3. Algal pigments

Chlorophyll a is a well-accepted index for phytoplankton abundance and population of primary producers in an aquatic environment. It is a reliable and commonly used proxy for total phytoplankton biomass. In reservoirs chlorophyll *a* concentration generally ranges between 3.49 and 47.34 μgL^{-1} (Gregor and Marsalek, 2004). The average Chlorophyll *a* was quantified in 2007-08 for this reservoir was16.6 μgL^{-1} which reduced to11.6 μgL^{-1} in the succeeding year 2008-2009, corresponding to the decline in plankton count. The other pigments chlorophyll *b* and *c*, carotenoids are also estimated. The average chlorophyll *b* also showed similar trend measuring 23.2 μgL^{-1} and 18.1 μgL^{-1} in 2007-08 and 2008-2009, respectively. Chlorophyll *c* pigments of annual average recorded very high values 159.3μgL^{-1} in 2007-08 and plummeted to 26.1 μgL^{-1} in the following year. Carotenoids are the other pigments estimated which are responsible for bright colors in various biological organisms and accumulated in chloroplasts in all green plants. The average carotenoid concentration showed no significant difference between two years recording 33.4 and 32.2 in both the year (Fig.5). Algal biomass in wet and dry condition and phytoplankton carbon were also estimated and given in Fig.6.

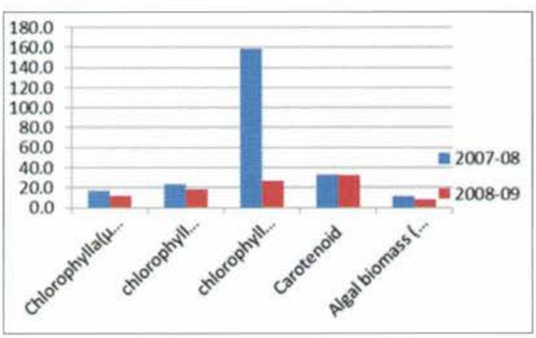

Fig. 5. Algal pigments

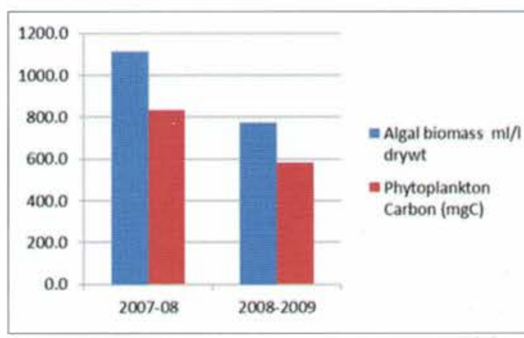

Fig. 6. Algal biomass and phytoplankton carbon

4.4. Carbon synthesis

Primary production or carbon synthesis is a variable complex and function of available nutrients and intensity of light. The primary production of the reservoir was estimated every month. The quarterly average gross carbon synthesis in Kanhirapuzha reservoir fluctuated from 16.66 to 64.23 mgC m^{-3} hr^{-1}during the study period and the net primary production from 5.20 to 48.35 mgC m^{-3} hr^{-1}.The community respiration recorded in this reservoir ranged from a low13.12 to moderate 42.04 mgC m^{-3} hr^{-1}. The Net:Gross ratio recorded higher value (1.56) during peak monsoon season July-September 2007, indicating corresponding maximum net photosynthetic activity and so also respiration. During Oct – Dec 2007 late monsoon, the P: R ratio was high (2.49), indicating that the community respiration is lower while net production had not significantly subsided (Table 3).

Table. 3 Primary production

S. No.	PERIOD	GPP	NPP	RES	N:G	P:R
1.	JUL - SEP 07	16.66	26.04	30.21	1.56	0.55
2.	OCT - DEC 07	34.69	48.35	13.88	1.39	2.49
3.	JAN - MAR 08	19.18	26.38	28.21	1.37	0.67
4.	APR - JUN 08	18.23	10.41	15.62	0.57	1.16
5.	JUL - SEP 08	19.92	12.36	13.12	0.62	1.51
6.	OCT - DEC 08	33.85	5.20	28.64	0.15	1.18
7.	JAN - MAR 09	59.89	17.79	42.04	0.29	1.42
8.	APR - JUN 09	64.23	25.94	35.58	0.40	1.80

4.5 Energy flow of the reservoir

The process of energy transformation by chlorophyll bearing photosynthetic organisms from solar electromagnetic radiation to chemical energy (primary production) and to fish production is given below. The percentage conversion of primary production to fish yield of Kanhirapuzha reservoir (0.013) is lower compared to some of the Indian reservoirs (Bhavanisagar: 0.182, Nagarjunasagar: 0.0456, Rihand: 0.0311, Govindsagar: 0.123).

1. Light energy to Primary production - 0.35 %
2. Light energy to fish production - 0.00047 %
3. Primary production to fish yield - 0.013 %

5. Aquatic Biodiversity

5.1 Planktonic community

One of the most important living organisms in the aquatic ecosystem is plankton. The phytoplankton, the primary producer, plays an important role in the material circulation and energy flow in the aquatic ecosystem. Its presence often controls the growth, reproduction capacity and population characteristics of other aquatic organisms (Ariyadej *et al.*, 2008).

Species diversity

The plankton species composition of the Kanhirapuzha reservoir is unique, predominated by species of desmidaceae (Table.4) in all the stations during 2007-2008. Composition of algal species from 2007-08 has been depicted in Fig. 9. However in site S5, dinophyceae sharing 31.8% of the total plankton count is the second dominant algae, consisting of *Ceratium* sp, *Gymnodinium* sp. and *Peridinium* sp. During 2008-09, desmidaceae takes substantial proportion constituting above 95% in all the stations (Fig.10).

Table 4. Percentage spatial distribution of plankton during 2007-08

Family	S1	S2	S3	S4	S5
Bacillariophycae	0.5	0.3	5.8	0.1	0.4
Chlorophyceae	3.2	2.5	3.1	1.5	4.2
Desmidiaceae	91.9	90.3	79.1	78.5	48.5
Dinophyceae	1.3	3.8	6.9	5.7	31.8
Myxophyceae	1.0	1.3	1.7	2.9	6.4
Rotifera	1.4	1.3	2.6	4.6	6.7
Protozoa	0.7	0.4	0.8	6.7	2.1

The average plankton total count site wise for 2007-08 and 2008-09 is depicted in Fig.7. The average total plankton count registered 9276 Nos.l^{-1}, 12504 Nos.l^{-1}, 7090 Nos.l^{-1}, 30780 Nos.l^{-1}, 55050 Nos.l^{-1} at sites S1, S2, S3, S4, and S5 respectively during 2007-08. Obviously, less disturbed sites S2, S4 and S5 outnumbered other sites. It is apparent the river zone, lotic (S3), recorded the least count due to continuous movement of running water which dislocated the standing crop. The average plankton count for 2008-09 drastically declined registering 3839 nos.l^{-1}, 63 nos.l^{-1}, 1055 nos.l^{-1}, 1131 nos.l^{-1} and 980 at S1, S2, S3, S4 and S5 respectively. It is evident to note that S5 where water is comparatively stagnant recorded very poor counts probably indicating the intensive grazing by fish fingerlings stocked from August 2008 onwards.

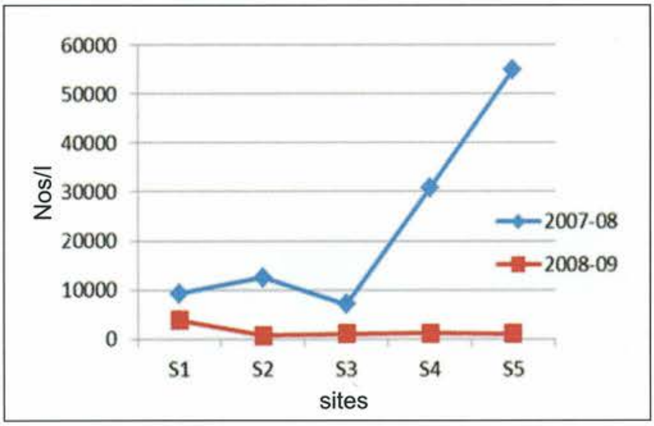

Fig. 7. Site wise variation in average total count in 2007-08 and 2008-09

The spatio-temporal changes during 2007-08 in the abundance of plankton at respective sites as illustrated in Fig.6 ranged from 1425 nos.l^{-1} (August 2007) to 113876 nos.l^{-1} (July 2008) during 2007-2008. During July 2008, a bloom of *Ceratium* sp. and *Gonatozygon* sp.at sites S4 (intermediate) and S5 (between hillocks) was observed, recording density of 221840 nos.l^{-1} and 333460 nos.l^{-1} respectively. Temporally the average plankton count showed significant difference in both the years 2007-08 and 2008-09. In 2008-2009 the average plankton count ranged from 69 nos.l^{-1} (April 09) to 3016 nos.l^{-1} (May 09). During May'09 there was a bloom of *Genicularia* sp. in site S4 and site S5 which marginally increased the total count.

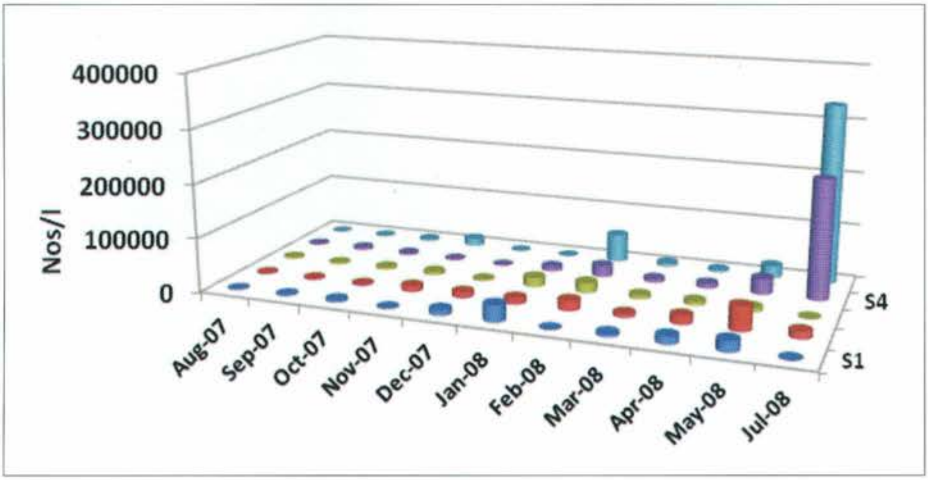

Fig. 8. Spatio-temporal distribution of plankton during 2007-08

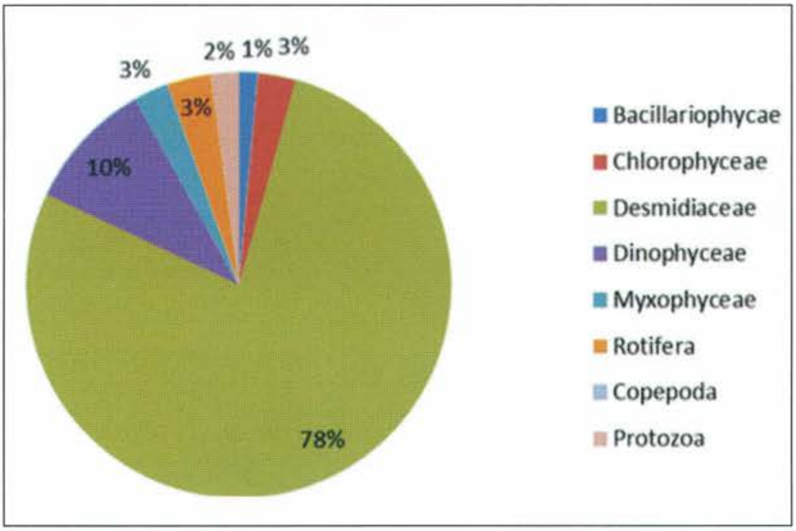

Fig. 9. Composition of algal species in 2007-2008

The predominant plankton population in this reservoir come under desmidiaceae which is represented chiefly by species of *Gonatozygon, Genicularia*, *Staurastrum, Closterium* and *Arthrodesmus*. The percentage representation of different species of desmidaceae is given in Fig. 10. The plankton forms occurred in Kanhirapuzha reservoir is accounted in Table.5.

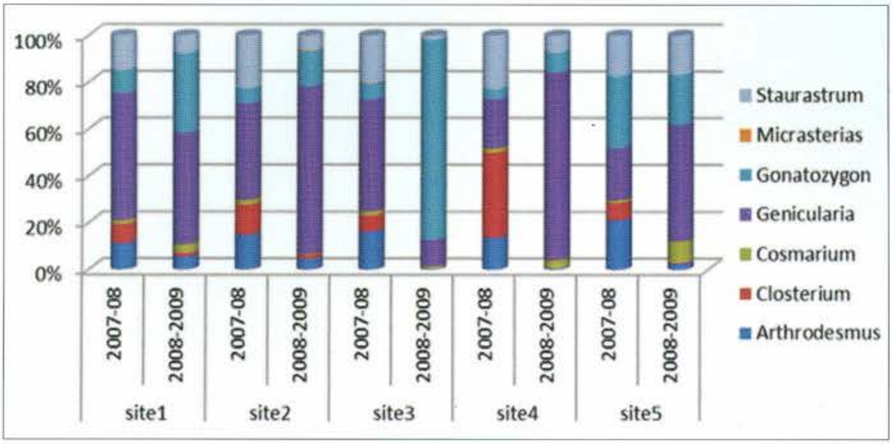

Fig. 10. Percentage contribution of desmid species

5.2 Bottom biota

Chironomus sp. and Polychaetes shared the major proportion of macrobenthos (Fig.11). During April and May 2009, bivalve, *Lamellidens marginalis*, and gastropods *Assiminea brevicula, Villorita cyprinoides* were observed in the littoral zones of the reservoir. *Chironomus* sp. registered an average of 669 nos.m^{-2}, the highest being at site S5 recording 913 nos.m^{-2}. Polychaetes recorded an average of 183 nos.m^{-2}, the maximum presence being at site S5. The reservoir bottom area is largely covered by laterite rocks and there is poor prospect for proliferation of benthos.

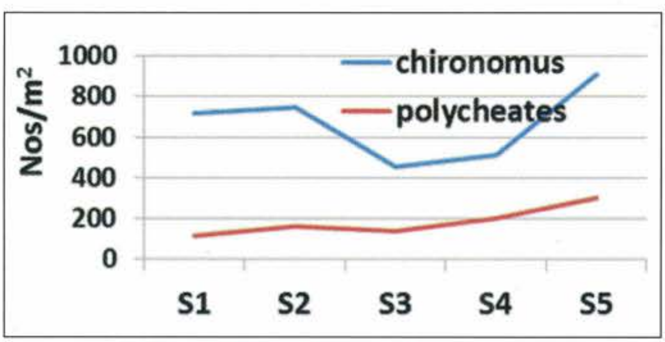

Fig. 11. Population of Benthos

5.3 Fish fauna

A total of 25 species of fishes and shell fishes under 12 families and 8 orders of fish fauna including scampi and molluscans were recorded (Table 6). Fishery of this reservoir was mainly supported by the family Cyprinidae which comprised stocked fishes *Catla catla,*

Table 5. Plankton forms in Kanhirapuzha reservoir

Bacillariophyceae	Chlorophyceae	Desmidiaceae	Dinophyceae	Myxophyceae	Cyanophyceae	Rotifera	Protozoa
Biddulphia	*Ankistro desmus*	*Arthodesmus*	*Ceratium*	*Microcystis*	*Botryococcus*	*Asplanchna*	*Difflugia*
Coscinodiscus	*Selenastrum*	*Closterium*	*Goniaulax*	*Spirulina*		*Brachionus*	*Rhizopoda*
Cyclotella	*Cladophora*	*Cosmarium*	*Gymnodium*			*Evadne*	
Navicula	*Coelastrum*	*Desmidium*	*Peridinium*			*Filinia*	
Nitzschia	*Dictyosphaerium*	*Genicularia*				*Keratella*	
Pinnularia	*Dimorphococcus*	*Gonatozygon*				*Lecane*	
Pleurosigma	*Kirchneriella*	*Micrasterias*				*Polyarthra*	
Surirella	*Microspora*	*Staurastrum*				*Proales*	
Tabellaria	*Monostroma*	*Xanthidium*				*Scaridium*	
	Pediastrum					*Testudinella*	
	Planktosphaeria					*Trichocerca*	
	Scenedesmus						
	Sphaerocystis						
	Westella						

Cirrhinus mrigala, Labeo rohita, Cyprinus carpio and *Ctenopharyngodon idella* and native fishes *Puntius filamentosus, Puntius sophore, Gonoproktopterus curmuca* and *Amblypharyngodon mola.*

Table 6. Icthyofauna and shellfish of Kanhirapuzha reservoir

S. No.	SPECIES	FAMILY
	Cypriniformes	
1	*Catla catla*	Cyprinidae
2	*Labeo rohita*	Cyprinidae
3	*Cirrhinus mrigala*	Cyprinidae
4	*Cyprinus carpio*	Cyprinidae
5	*Ctenopharyngodon idella*	Cyprinidae
6	*Garra mcclellandi*	Cyprinidae
7	*Garra mullya*	Cyprinidae
8	*Puntius filamentosus*	Cyprinidae
9	*Puntius sophore*	Cyprinidae
10	*Gonoproktopterus curmuca*	Cyprinidae
11	*Amblypharyngodon mola*	Cyprinidae
12	*Salmostoma* sp.	Cyprinidae
	Siluriformes	
13	*Ompok bimaculatus*	Siluridae
14	*Mystus armatus*	Siluridae
15	*Clarias batrachus*	Clariidae
	Perciformes	
16	*Etroplus suratensis*	Cichlidae
17	*Etroplus maculatus*	Cichlidae
18	*Channa striatus*	Channidae
19	*Glossogobius giuris*	Gobiidae
	Symbranchiformes	
20	*Mastacembelus armatus*	Mastacembellidae
	Clupeiformes	
21	*Stolephorus* sp.	Engraulidae
	Crustaceae	
22	*Macrobrachium rosenbergii*	Penaeidae
	Bivalvia	
23	*Lamelladens marginalis*	Unionidae
24	*Villorita cyprinoides*	Corbiculidae
	Gastropoda	
	Littorinimorpha	
25	*Assiminea brevicula*	Assimineidae

6. Biology of selected indigenous fishes

6.1 Gonoproktopterus curmuca

G. curmuca is one of the dominant native fish observed in the daily fish catch of Kanhirapuzha reservoir. It is an omnivorous, gregarious species that normally occupy deep waters in the rivers of the plains or in deep and cool pools in hilly regions and as adults migrate to smaller tributaries and streams for spawning. The species is seen mostly along the banks of rivers. It attains a maximum length of 30 cm, is a bottom feeder, and hence have a suitable downward facing mouth. Adult males develop tubercles on the snout. It is known to breed after the south-west monsoon months, from June to August.

Length weight of fishes

The length and weight of the fish ranged from 175 to 352 mm and 40 to 470 g respectively in the fish samples collected under this period ofstudy. The length-weight relationships of male, female and both sexes were analysed and the linear equations are for

Male: Log W= -5.1722+3.0787 log L R^2 = 0.8038.

Female: log W= - 5.2554+3.1155 log L. R^2 =0.7376

Male-Female combined. : Log W = - 5.2053 + 3.0933 log L. R^2 =0.7788

Diet composition of *Gonoproktopterus curmuca*

The gut contents analysis of *G. curmuca* showed an average percentage of detritus and decayed matter (62.4%) and sand (25.3%) were dominantly present (Fig.12). The other constituents in the diet are chlorophyceae (0.69%), desmidiaceae (2.29%), bacillariophyceae (1.76 %), myxophyceae (0.67%), dinoflagellates (0.13%), rotifers (0.70%), cladoceran (1.16%), copepod (1.68%), protozoa (0.56%) and others (2.7 %).

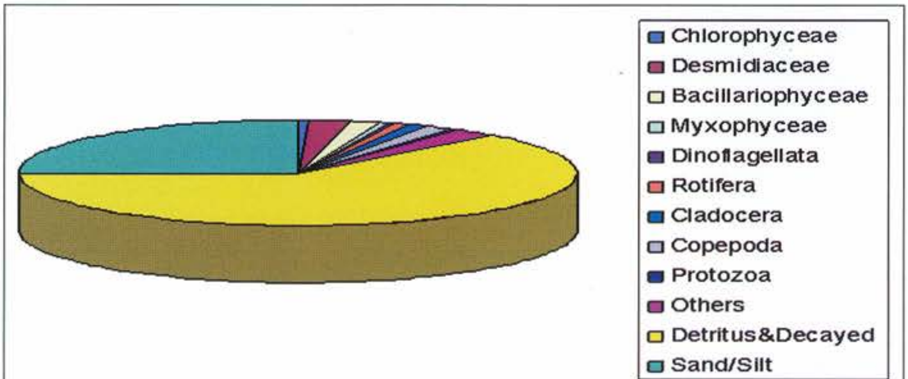

Fig.12. Food habitat of *G. curmuca*

6.2 Puntius filamentosus

Puntius filamentosus is a dominant native fish in Kanhirapuzha reservoir and its consumer preference in the surrounding area is impressive. Of late, they are gaining significance in terms of gene banking (Myers *et al.* 2000). Two species, *P. filamentosus* and *P. sophore* are caught from Kanhirapuzha reservoir. However *P. filamentosus* outnumbered *P. sophore* and is observed throughout the year. The length weight relationship of *P. filamentosus* is given below.

Length weight of fishes

A total of 225 samples of *Puntius filamentosus,* ranging from 78 to 200 mm in length and 6.0to 250.0 g weight, were collected from the catches of the reservoir at monthly intervals from April 2010 to March 2011. The coefficient of determination, the R^2 values obtained were significant at 1% level.

MALE: $\text{Log } W = -5.3685+3.2392 \log L, R^2 = 0.9538$
FEMALE: $\text{Log } W = -5.7150 +3.4243 \log L, R^2 =0.9221$
COMBINED: $\text{Log } W= -5.4480+3.2987 \log L, R^2 = 0.9043$

Reproductive cycle of fish

Five ovarian development stages from immature, early maturing, advanced maturing, ripe and spent were observed and the cycle repeated twice in a year with ripe stage conspicuous in May-June with high fecundity while in October to February it was sporadic with comparatively less number of ova. The Gonado-somatic index (GSI) attained peak during June (9.6) and January(8.1) and the mean value for the period of study was 3.7.

Diet composition

The gut content revealed that detritus (85%) occupied the major portion followed by sand (3%). The contribution of chlorophyceae, bacillariophyceae, desmidiaceae and myxophyceae were evenly distributed at 2% share. 32 genera of plankton were recorded from the gut, out of which 25 are phytoplankton and 7 are zooplankton. Chlorophyceae was dominated by species of *Monostroma*, *Cladophora* and *Microspora.* Dominant among bacillariophyceae were *Navicula* sp., *Nitzschia* sp. and *Synedra* sp. *Microcystis* contributed major portion of myxophyceae. Among zooplankton, rotifers outnumbered copepoda and cladocera and dominant species are *Polyarthra* sp., *Brachionus* sp. and *Tricocerca* sp.

7. Fisheries

Kanhirapuzha is a low productive reservoir by virtue of its oligotrophic nature. It is a culture based reservoir, which depends on artificial recruitment for enhancement of fish production and natural productivity for growth. The indigenous fishery poorly supports the total yield. Its fish production potential was estimated at 159.4 t (309.7 kg per ha) as per the conversion of primary production to fish yield which was 0.013% against potential conversion rate of 1.2% suggested by Odum (1960). The maximum yield attained during these years was only 11743.8 kg (25.98 kg per ha) in 1991. Enhanced yield may be achieved through better management measures including optimum stocking size, stocking density, species composition and effective harvesting practices. Hence formulation of new management strategies based on the scientific data is essential to improve the fish yield from this reservoir. Meagre catch led very few fishermen venturing into fishing as a part time occupation to obtain a minimum catch of 3-4 kg of fish per day. Fibreglass coracle and HDPE mono-filament nets are the main craft and gears used only in few selected reservoirs including Kanhirapuzha. There is an ample scope of improving the production through appropriate management strategies to achieve reservoir's fish production potential.

Fig. 13. Fibreglass coracle used as craft for fishing

Fig. 14. Fishermen collecting the native fishes from the nets

7.1. Stock and yield (1988-2007)

Fish seed stocking commenced in this reservoir since 1988 by the department of fisheries and the SC/ST fishermen cooperative society except for few years. The stocking rate ranged from the lowest 142 Nos.ha^{-1}(1991-1992) to the highest 3557 Nos.ha^{-1}(1995-1996) (Fig.15). The species composition of the stocking consisted Indian major carps *Catla catla, Cirrhinus mrigala, Labeo rohita,* and exotic fishes common carp *Cyprinus carpio* and grass carp *Ctenopharyngodon idella* and scampi *Macrobrachium rosenbergii.* During this period the average percentage sharing of stocking by *Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo fimbriatus, Cyprinus carpio, Macrobrachium rosenbergii* were 21.8 %, 18.6% , 32.8%, 17.6%, 7.8% and 1.5%, respectively.

The landings recorded for the period 1988-2007 ranged from 2303.2 kg per yr to 11743.8 kg per yr accounting 5.1 kg per ha to 24.95 kg per ha (Fig.16). Among the stocked species, only *Catla catla* and *Cirrhinus mrigala* were caught in return considerably, whereas, *Labeo rohita* was absent or very poor in all the years. Among the unstocked varieties, *Gonoproktopterus curmuca* (Av. 298 mm; 225 g), *Amblypharyngodon mola* (Av. 105mm; 20 g), *Puntius filamentosus* (Av.181mm; 65 g) and *Ompok bimaculatus* (Av.350 mm; 280 g) contributed to the total yield. *Etroplus maculatus* and *Garra* sp. are rarely found in the catch.

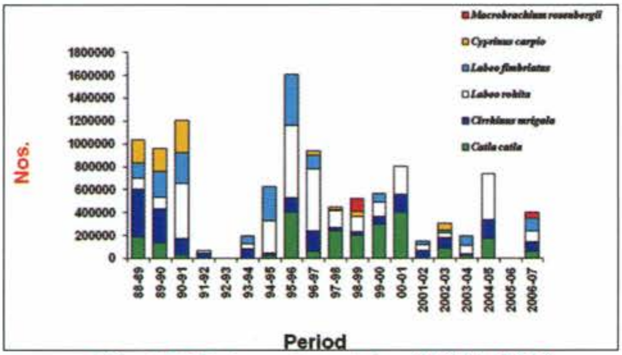

Fig. 15. Fish seed stocking (1988-2007)

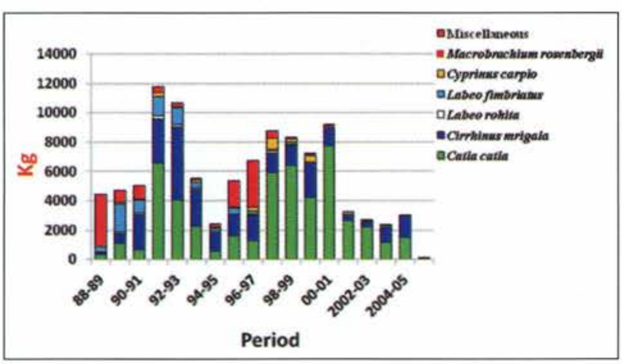

Fig. 16. Fish yield (1988-2006)

7.2 Management of culture based fisheries (2008-2011)

Kanhirapuzha is a perennial reservoir with no water scarcity. This favours the fishes to grow till the marketable size round the year with no impact of seasonal fluctuations of water level. Carnivorous fishes are absent in this reservoir aiding the reduced predation to stocked fishes. Local demand for Kanhirapuzha reservoir fish is very high for their unique taste. All these merit the Kanhirapuzha reservoir for the development of culture based reservoir.This reservoir is arbitrarily stocked with fries and fingerlings of major carps of variable size and numbers. Hence it is essential to stock the reservoir with CIFRI recommended optimum size of 100 mm fingerlings (Selvaraj *et al.*,1995). To stock the reservoir, 10 cm size fingerlings were raised in both land based and reservoir *in-situ* nurseries.

7.2.1 Raising stock size IMC fingerlings

(a) Land based nurseries:

Adjacent to the reservoir, 11 nursery ponds covering an area of 2.3 ha owned by Irrigation department of Kerala was cleared of weeds to stock the spawns of IMC. Bundhs were constructed and pipes connecting the ponds inlets and outlets were laid. Ponds were filled with water from the adjacent canal to test its water retention capacity.

Fig. 17. Netting in land based nurseries

These nursery ponds were utilized to rear fingerlings upto stockable size (10 cm) by regular manuring with cow dung @ 1000 kg/ha and lime @ 100 kg/ha which promoted the growth of plankton in the ponds. Supplementary feed with a mixture of rice bran (60%), groundnut cake (30%) and soya meal (10%) was provided twice daily to the fish fry. Four lakh fry of Catla and 3 lakh fry of Mrigal were purchased from private hatchery and stocked in nursery ponds to grow upto stockable size. Seeds are harvested in drag nets and about 10 cm size fingerlings segregated and acclimatised in the adjacent river in hapa nets and then released into the reservoir.

Fig. 18. Harvesting fingerlings for stocking in reservoir

Fig. 19. Releasing the fingerlings in open reservoir

(b) Reservoir in-situ nurseries

The seed rearing was also attempted in two cages of size 4mx4mx2m fixed in open reservoir where water circulation was less. The cages were fabricated out of the HDPE woven material (40x40 mesh/inch). These set up were fitted firmly with the bamboo poles and secured at the bottom and the tops of the nets are fastened with the strong branches of the trees. About 300000 nos. of 3 day-old spawns of common carp were stocked but unfortunately the nets collapsed during October 2009 following heavy monsoon rain.

Fig. 20. In-situ nursery rearing

7.2.2. Stocking of IMC seeds by external agencies

A total of 465401 carp seeds and 5 lakh scampi seeds were stocked during this year (2008-09). A total of 68401 nos. of fingerlings of 9-10 cm size (4006 nos. of catla and 64395 of mrigal) were also stocked by CIFRI. Meanwhile the NFDB, Hyderabad had sanctioned the financial assistance of 8.50 lakhs to Kanhirapuzha reservoir to stock fingerlings at the rate of 2000 nos.ha^{-1}. The local zilla parishad under backward region grant fund has also assisted financially to the Fishermen Co-operative Society to stock 5.0 lakh scampi seeds. The stocking details for 2008-2009 and 2009-2010 is presented in Table 7 and 8.

Table 7. Details of stocking by different agencies. (2008-09)

Species	2008 -2009	2009 - 2010
Catla	46006 (9.8)*	230500 (26.5)
Mrigal	189395 (40.7)	248100 (28.5)
Rohu	205000 (44.0)	24 000 (3 7.3)
Grass carp	25000 (5.4)	-
Common carp		66250(7.6)
Scampi	500000	-
Total	465401	86 8250
Stocking (Nos./ha)	909	169 6

Table 8. Species wise stocking details during 2008-2010

S. No.	Agencies	Catla	Rohu	Mrigal	Grass carp	Scampi	Common carp
1.	BRGF					500000	
2.	CIFRI	4006		64395			300000 (SPAWN)
3.	NFDB	42000	205000	125000	25000		
	TOTAL	**46006**	**205000**	**189395**	**25000**	**500000**	

*Percentage given in parenthesis

7.2.3 Growth monitoring of fish population (2008-09 and 2009-10)

The growth rate of fingerlings of Indian major carps stocked in Kanhirapuzha reservoir were studied by length weight measurement of fishes collected by experimental fishing. The fingerlings were stocked at the density of 909 nos.ha^{-1} and 1696 nos.ha^{-1} during 2008-2009 and 2009-2010 respectively. Among the fishes stocked, the catla and mrigal were recaptured in considerable numbers. The length weight data on temporal basis were collected for seeds of cohort stocked during 2008-2009 by experimental fishing for the preliminary estimates of growth parameters.

7.2.4 Analysis of length frequency data and population dynamics of stocked fishes

The length frequency composition of *Catla catla* and *Cirrhinus mrigala* and their increase in weight at monthly intervals are given in the Fig 13,14 and 15, respectively.

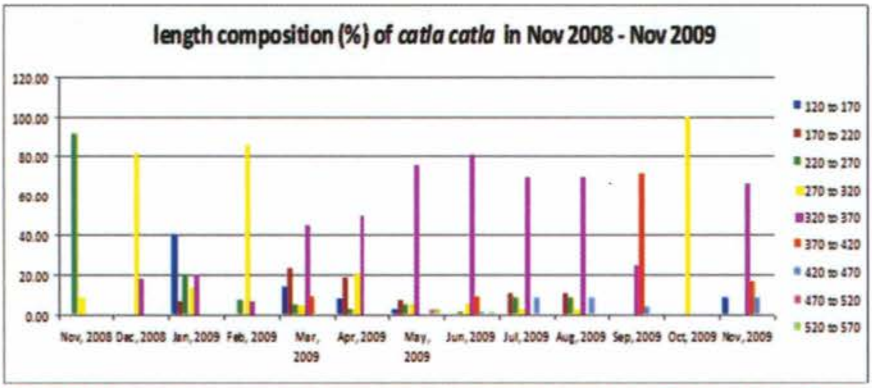

Fig. 21. Length composition (%) of *Catla catla* in Nov 2008 – Nov 2009

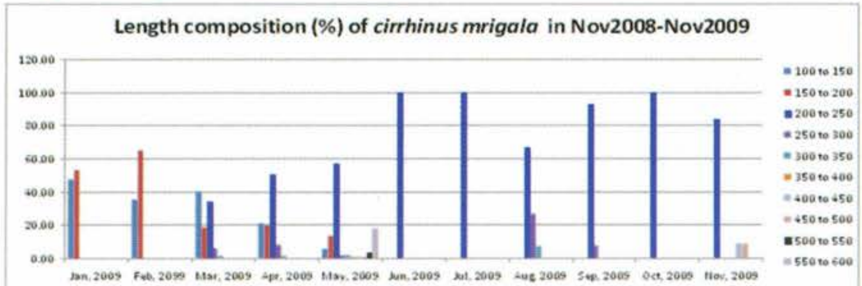

Fig. 22. Length composition (%) of *C. mrigala* in Nov 2008 – Nov 2009

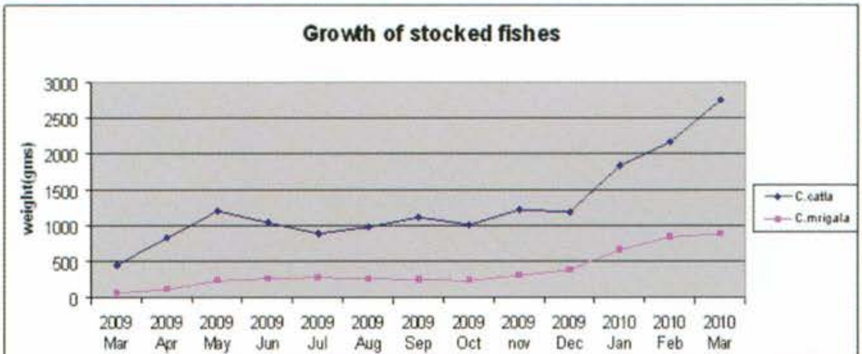

Fig. 23. Growth of stocked fishes

The growth of *Catla catla* is excellent in this reservoir (Fig.24). The length class of 320 - 370 mm, corresponding to weight ranging from 825 to 1125 g, was achieved from 7th month after stocking. This length group of catla was dominant from 7th month to 12th month since stocking time and mostly caught by 100 and 125 mm mesh size nets. Catla weighing more than 2.0 kg are caught in 180 mm mesh net after 14th month from stocking. Fingerlings of *Catla catla* were stocked at the density of 90 nos. ha^{-1} and 450 nos. ha^{-1} in 2008-09 and 2009-10, respectively. Catla attained about 150.0 g after 16th month, 2500 g after 18 months of stocking which is better than the mrigal growth. *Cirrhinus mrigala* attained 200 - 250 mm in length corresponding to weight ranging 180 to 390 g at 7th month and this length group persisted in dominance in the succeeding 8 months. The growth of mrigal is comparatively very low (Fig. 25) and they reached an average of 800 g after 18th month from stocking time. The recapture of *Labeo rohita* were negligible (8 nos.) indicating stocking this species in this reservoir is ineffective. The stocking of Grass carp was also unsuccessful for there was no recapture of this speciesduringexperimental fishing. Recapture at the 7th month started from stocking and subsequent months serially numbered in the X axis of the figure.

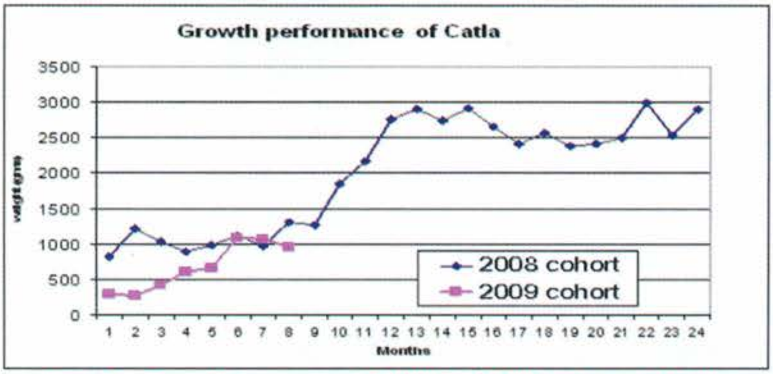

Fig. 24. Growth increment of 2008 &2009 cohorts of Catla

The length-weight data indicate that these two fishes, catla and mrigal support the fishery of Kanhirapuzha reservoir in a major way. The catla and mrigal of 2008-2009 cohorts take nearly 24 months to reach its maximum harvestable size of 3.0 kg and 1.250 kg respectively. Comparing the growth performance of catla of two sets of experiments, the 2008-09 cohort outperformed the 2009-2010 cohort registering 1122.0 g (at 89 $nos.ha^{-1}$ of stocking density) over to 1070 g (at 447 $nos.ha^{-1}$) after a span of 12 months. In case of mrigal, the significant growth difference between the two batches were not observed at stocking density of 368 $nos.ha^{-1}$ (2008-09) and 482 $nos.ha^{-1}$ (2009-2010).

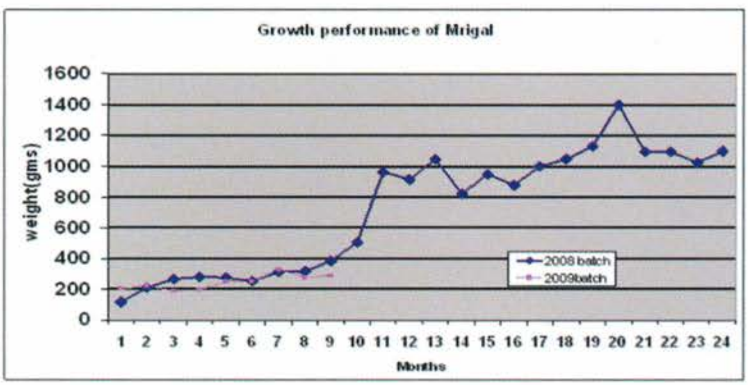

Fig. 25. Growth performance of 2008 & 2009 cohorts of Mrigal

7.2.5 *Estimation of optimum stocking density of fish fingerlings*

The length frequency data were analysed for estimating the population parameters for the *Catla catla* and *Cirrhinus mrigala* of 1st cohort using FISAT II software. The growth coefficient (K/yr) was assessed through VBGF model and it was 0.73 for catla being better than mrigal (0.33). Similarly the asymptotic length ($L\infty$) by ELEFAN II software determined. The asymptotic length for catla is 1066 mm at the stocking density of 89 nos. ha^{-1} and mrigal, 886 mm at the stocking density of 368nos.ha^{-1}. The total mortality (Z) was calculated by length converted catch curve and it is 4.3 for catla and 0.59 for mrigal. Pauly's empirical formula was used for estimating the natural mortality (M). Fishing mortality (F) [was estimated from total mortality and natural mortality] (F = Z-M). The growth performance index was very good for catla being 5.89 and for mrigal 1.78. The VPA and cohort analyses by Jones predicted the biomass available for exploitation for catla and mrigal were 18.7 t at mid length 510 mm and 123.0 t at 460 mm, respectively (Fig.26).

For the optimization of stocking and harvesting regimes at the Kanhirapuzha reservoir, Lorenzen's (1996) von Bertalanffy growth model was used for analysis of the data to find out the optimum stocking density of *Catla catla* alone to stock in this reservoir. The length weight frequency data collected for the two years were subjected to the Density dependent Growth Model proposed by Lorenzen (2000). The output established that at the combination of fishing mortality (F) of 1.8 - 2.1 and stocking rate around 350 nos. ha^{-1} would fetch the maximum fish production 90 kg/ha^{-1} from this reservoir (Fig. 26).

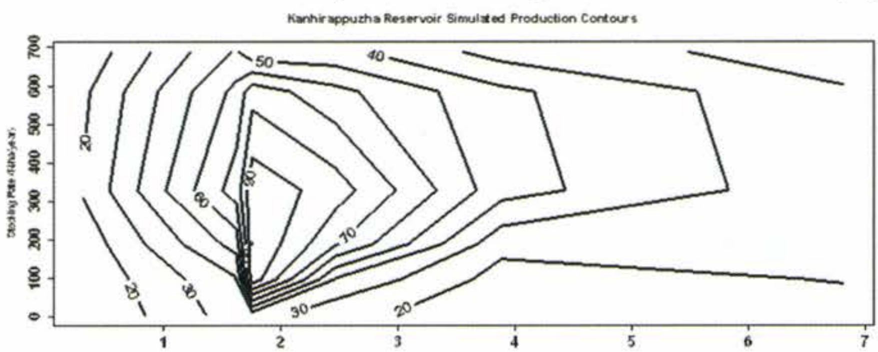

Fig. 26. Simulated production contours of Kanhirapuzha reservoir

Kanhirapuzha Reservoir : Equi-Production Contours (Catla), F (Fishing mortality) range from 0 to 7 (/year), Stockingrate : 0 to 700 Nos., Production (Kg/hectare/year), A simulation exercise involving 121 combinations of F and Stocking rate, Optimum combination F=1.8- 2.1 Stocking rate-200-400 Maxi production= 90 kg/ha/yr

8. Post-stocking yield

Stocked fishes, particularly catla and mrigal, of one year age, commenced to come in the landings from January 2010 increasing the total yield in 2010 and 2011. The unstocked varieties were sub-dominant, chiefly consisting of native fishes, *viz*. *Amblypharyngodon mola, Gonoproktopterus curmuca* and *Puntius* sp. The recapture of scampi was poor in spite of their good growth and intensive stocking (Fig. 27). In 2010, the catla yield recorded 1610 kg and for mrigal it was 3014 kg.

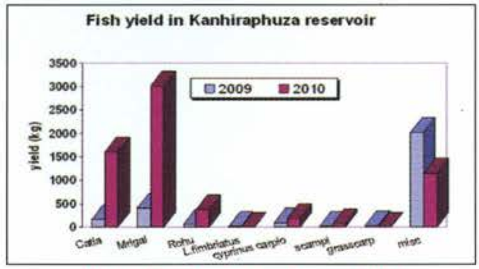

Fig. 27. Post stocking yield

Fig. 28. Major carps landings from the reservoir

Fig. 29. A day's catch of Indian major carps

Fig. 30. Catla caught from the reservoir

Fig. 31. *Amblypharyngodon mola* and *Puntius filamentosus* landings from the reservoir

Fig. 32. Stocked *Macrobrachium rosenbergii* landings

9. Socio-economic status

The socio-economic status of fishermen of the Kanhirapuzha reservoir was studied for the period under report. The fishermen belong to the SC/ST Cooperative fisheries society. About 126 fishermen are members of the society. Sampling was done by collecting information from ten active fishers out of 30 fishermen operating in this reservoir. Majority of the fishermen have a middle level of educational background. The demographic pattern of the fishermen community is in the ratio of 1:1.5. The head of the family is the sole earning member mainly through fishing and as labour being the subsidiary occupation. The literacy level of the fishing family mainly comprised of primary level of education followed by matriculation. The assets of the fishermen mainly consist of pucca housing with average area of 300 sq.ft. Among the fishery requisites, the fisherman does not have their own crafts, since the coracle made of fiberglass material is provided by the department of fisheries. All the fishermen own gillnets made up of monofilament nylon material with the mesh size ranging from 20 mm to 250 mm. The fishery activity here is capture fisheries and carried out individually by the fishermen in the reservoir. It indicates that the time devoted during the three periods viz., lean, medium and peak months is same (*i.e.*) 12 hours, whereas the catch is approximately 2, 4 and 8 kg/day during the lean, medium and peak seasons, respectively. The main income for the fishermen is approximately Rs.14000 per annum and the subsidiary income of the individuals varies. The members of cooperative fishermen society should be supplied with all facilities for year round fishing. Fishermen need training on the recapture of stocked fishes on mesh size, nylon nets instead of monofilament, hauling of nets etc.

Fig. 33. Discussion with the fisherfolk

10. Salient findings

1. The growth performances of catla and mrigal are significant and are best suited for stocking in this reservoir. The optimum stocking density for catla was estimated at 250-350 nos.ha^{-1} as per Lorenzen's density dependent growth model.
2. This reservoir is unsuitable for stocking rohu, grass carp and scampi.
3. Harvesting catla at mid-length between 410-510 mm would give better yield at stocking density (250-350Nos.ha^{-1}). The optimum mesh sizes of nets to capture catla of 1000-2000 g are 125 mm, 150 mm and 180 mm.

4. Harvesting mrigal at length range 435 to 485 mm (0.950 to 1.5 kg) would give the highest yield at stocking density (368 nos. ha^{-1}) using nets of mesh size of 100 mm and 125 mm.
5. The major landing season is May - July. During this period fishing effort may be increased.

Constraints

1. The failure to recapture rohu, scampi and grass carp probably due to seed escapement by nature of their movement along with the river course or unfavourable habitat conditions for survival.
2. Seeds and surface dwelling fish *e.g.* catla are heavily predated by otters and birds.
3. Water level is not decreasing even in summer to facilitate easy harvesting.
4. During summer, surface water temperature is rising to 30.5° C, thus allowing the adult fishes taking shelter in deeper areas.

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