Ecology and Fisheries of Selected Reservoirs of Madhya Pradesh

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Foreword

Reservoirs, the prime inland fishery resource of India are unique biotopes comprising both lacustrine and fluviatile conditions. This ecosystem is undoubtedly lagging much behind in inland fish production of the country. Most of the reservoirs remained untapped to their full potential, even half of the potential is hardly achieved due to lack of proper understanding of the ecosystem and no scientific management. There is a wide gap between the potential and the actual fish yield which could easily be mitigated through eco-oriented management approach.

The Central Inland Fisheries Research Institute, Barrackpore has studied the "Ecology and fisheries of some selected reservoirs of Madhya Pradesh" during 1998-2003. The studies provide valuable information on present status of fisheries, existing problems and plausible measures to improve upon the fish production besides developing a suitable ecological database of these water bodies. I do hope that the results of this study will be of immense help to the State Government and concerned agencies for better management to obtain the maximum sustainable fish yield from these reservoirs.

I take this opportunity to express my sincere thanks to the officials of Fisheries and Irrigation departments of Madhya Pradesh for their excellent help and cooperation during the entire course of this study. All the scientists, technicians and staff of the Institute associated with this project also deserve a word of appreciation for their good work.

Director
CIFRI

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INTRODUCTION

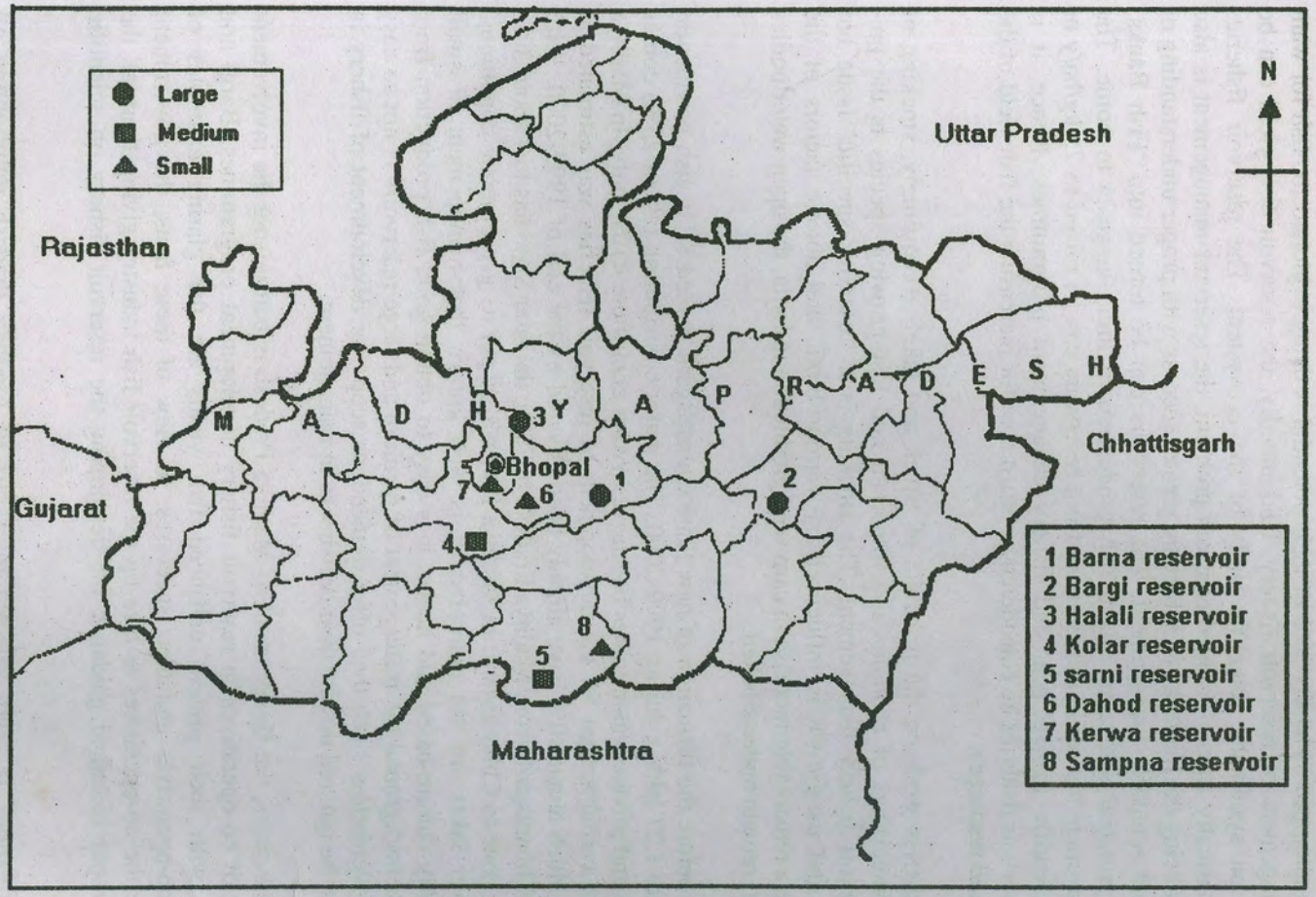
The reservoirs constitute the prime inland fishery resource of India with potentiality of 3.2 million ha of small, medium and large reservoirs. Unfortunately, this unique ecosystem is still lagging behind as far as the inland fish production of the country is concerned because the present fish yield from this resource is contributing less than 5% of the total fish yield. Most of the reservoirs are untapped as hardly 50% of their potential is being exploited for fish for want of adequate management of reservoir fishery. Undoubtedly, the reservoir fish yield can be enhanced based on systematic scientific study of the ecosystem. The reservoir fisheries development is basically an eco-oriented research problem, the reservoir management is also equally important being the mainstay of achieving greater success with proper understanding of the ecosystem and scientific management. The reservoirs can be turned into 'Fish Banks' constituting the principal source of inland fish production in India in years to come. The present national average low yield (30 kg/ha/y) from reservoirs can be raised to 75 kg/ha/y or more through scientific management and fishery enhancement programmes. Hence, it is necessary that reservoir fisheries be considered as thrust area for increasing the fish yield of the country from inland resources.

The reservoir fisheries work on the principle of 'stock and take'. Accordingly, stocking of reservoirs with fingerlings of economically important and fast growing species is the pre-requisite of reservoir fishery management. The stocking is a 'reservoir specific' issue but survival of fish and its growth is influenced by various biotic and abiotic factors of the reservoir. Despite a remarkable increase in carp seed production in India, the open water bodies of the country still remain under-stocked.

Madhya Pradesh before the formation of new State Chhattisgarh ranked 8th in fish production in the country with 1.27 lakh t during 1999-2000. The major contribution (about 75%) comes from ponds/tanks and private water bodies but the reservoirs contribute <10% only. In Madhya Pradesh, the total available area for the development of reservoir fisheries was estimated at 2.25 lakh ha, of which about 90% have already been covered by the end of 1999-2000. With the separation of Chhattisgarh from Madhya Pradesh in 2000, the later State has lost about 30% of reservoir area, gone to Chhattisgarh. In Madhya Pradesh, as per its geo-climatic conditions, even the shallower lakes are not eutrophic. It is well known that management of small reservoirs is mainly culture-based and hence, it is easy to obtain good fish production from them. Against this background the management of medium and large reservoirs is not so easy and simple but nevertheless since they offer tremendous scope for development of fishery in future, they cannot be ignored despite their drawbacks in management.

During the last few years, the Government of Madhya Pradesh is patronising the involvement and participation of co-operatives in reservoir fishery development programmes. Bargi and Tawa reservoirs with their present enhanced fish yields are the glaring examples of participation of co-operatives and their successes. In view of these facts, the government should encourage the co-operatives to take up the reservoir fish industry giving them all the incentives and proper technical guidance for developing the reservoir fishery on scientific lines.

Ecological investigations in eight selected reservoirs of Madhya Pradesh representing all categories – large, medium and small from different river basins were carried out during 1998-99 to 2002-03. The studies gave useful information about the present status, problems and measures to improve the management to enhance the fish production of these reservoirs.



Location of M.P. reservoirs under study

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BARNA RESERVOIR

Barna is a major irrigation project having a storage reservoir on Barna river near Bari in district Raisen. Besides, the main dam, a saddle dam was also constructed which is 94.5 m long. The type of both the dams is straight gravity stone masonry concrete. The construction of this dam has affected 25 villages. It is about 115 km from Hoshangabad connected by a fair weather road via Obaidullaganj. The ecological investigations were carried out in this reservoir during 1998-99.

Salient morphometric and hydrographic features

Location	Raisen
Year of constuction	1975
River	Barna - tributary of river Narmada
Latitude	23° 5' N
Longitude	78° 7' E
Basin	Narmada
FRL (m)	348.55
Maximum depth (m)	33
Mean depth (m)	7
Water spread at FRL (ha) A	7700
Catchment area (km^2) C	1176
Catchment to reservoir area (C/A)	15
Productive area (ha)	4791
Gross capacity at FRL (10^6 m^3)	539
Shore line	60.3
Shore development	1.9
Volume development	0.64
Av. annual rainfall (mm)	1132
Purpose	Irrigation

During the period of investigations, a total inflow of 192.9 mcm (Jul-Sep) was observed, the flushing rate being low at 0.4 and 169.0 mcm water was outflown, the maximum being during Oct-Dec. The annual water level fluctuation was 3-4 m during the study period.

Sediment characteristics

A sound knowledge of the nature and properties of basin soil wherein a series of physical, chemical, biochemical and microbial reactions are continuously taking place resulting in release of different nutrients into the water phase is of utmost importance in determining the productivity of the ecosystem. The major physical and chemical features of soil are particle size distribution, types of clay, oxidation-reduction potential, soil reaction, electrical conductivity and nutrient dynamics.

A distinct colloidal, loose stratified organic layer followed by a clayey mineral layer of varying composition is ideal soil type at the reservoir basin for economic utilization of the nutrients. In Barna, basin soil was sandy loam in nature comprising 73.1% sand, 15.6% silt while clay content was 11.3%. In monsoons, with the inflow, more silt was loaded into the reservoir

making the reservoir more productive. Thus, studies of particle size distribution revealed that the basin sediment of Barna was ideal for productivity.

Amongst chemical features, soil reaction (pH) controls several chemical reactions responsible for availability of nutrients in optimum quantities to the environment for the growth and survival of biotic communities. Productive range of soil pH should lie in between 6.5 and 7.5. In Barna, soil reaction was near neutral (pH 6.5) to slightly acidic (pH 6.1) due to acidic nature of catchment soil.

Sediment characteristics of Barna reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average
Sand (%)	82.5	65.6	69.8	74.4	73.1
Silt (%)	9.2	20.3	18.4	14.5	15.6
Clay (%)	8.3	14.1	11.8	11.1	11.3
pH	6.3	6.1	6.4	6.5	6.3
Sp.cond (mS/cm)	0.11	0.13	0.16	0.17	0.14
Org.C (%)	0.38	0.66	0.53	0.80	0.59
Total-N(%)	0.025	0.033	0.024	0.044	0.032
C/N	15	20	22	18	18
Avail-N (mg/100g)	24.5	30.6	38.4	29.8	30.8
Avail-P (mg/100g)	0.20	0.68	0.85	0.50	0.56
Free $CaCO_3$ (%)	0.95	0.80	1.10	1.15	1.00

Specific conductivity, the representation of soluble salts in the bottom sediment does not necessarily attain high values so as to affect fish production. As the changes in electrical conductivity are associated with the release or depletion of soluble ions in the soil-water system, it definitely has an indirect role to play in reservoir productivity. In Barna, sp. conductivity was very low in the range (0.11-0.17 mS/cm) which may be due to slightly acidic nature of basin sediment.

Nitrogen and its role in fish nutrition is well known. It is the basic and primary constituent of protein. Nitrogen is basically present in soil in organic form, getting mineralized gradually to ammonium (NH_4^+) and nitrate (NO_3^-) forms thus making its acceptability to fish food organisms. In Barna, the available-N content was low to moderate (24.5 - 38.4 mg/100g).

Phosphorus, the assimilator of nitrogen into cellular matter, has been singled out as the most critical factor in maintaining productivity of aquatic ecosystem. Its importance is very much felt due to its lesser availability in Indian reservoirs. It is utilized by plankton in many forms. Organic-P constitutes about 30-40% of total-P. Inorganic-P, being very reactive, forms sparingly soluble iron and aluminium compound in acid soil and insoluble calcium phosphates in alkaline soil. So, its release from soil to water phase is restricted under both the extreme pH conditions. However, fixation of phosphorus into insoluble forms especially under aquatic system is not of permanent nature and in turn, the anaerobic condition in the bottom sediment develops congenial environment to increase the solubility of phosphorus through different mechanisms. In Barna, due to slightly acidic nature of soil, available-P was a limiting factor (0.20-0.85) but total-P was noticed to the extent of 3.02 mg/100g in monsoon in this reservoir, thus maintaining a reserve stock of phosphorus in the basin sediment.

Free $CaCO_3$, represents cationic load primarily in bottom sediment congenial for fish growth and productivity. In general, reservoirs having calcareous basin soil contains free $CaCO_3$ content to the extent of 4-6% or even more. But, reservoirs with acidic or slightly acidic basin soil have very meagre amount of $CaCO_3$. In Barna, its concentration was to the tune of 0.80-1.15% due to mild acidic nature of sediment.

Physico-chemical features of water

Prevailing water temperature plays a significant role in water metabolism and regulating different physiological processes in living organisms including fish which in turn depends on climate, sunlight and depth of water. In tropical Indian reservoirs, temperature is not a limiting factor and diel variation of water temperature ranges from 2-4°C and 10-12°C during post-monsoon and summer months respectively, exerting influence on plankton dynamics and availability of nutrients from soil to water phase. The rate of decomposition of bottom organic matter is enhanced in pre-monsoon with the increase in temperature, releasing available nutrients into the water phase which are easily accessible to plankton community. Samplings were done in between 9-10 A.M. while studying limno-chemical parameters of all reservoirs under study. In Barna, water temperature fluctuated to a low of 25°C in winter and a high of 31°C in pre-monsoon periods, with an average of 27.9°C being congenial for productivity. Productive water should be a little bit turbid as reflected in this reservoir having Secchi depth of low order in monsoon (0.75 m) due to suspended clay-micelles which got stabilised and settled in subsequent pre-monsoon periods resulting in increased transparency of water (Secchi depth 3.05 m). In summer, water level dropped to 6-8 m in this reservoir (mean depth 7m), thus exposing vast littoral areas, extending euphotic zone beyond 7.0 m with greater productivity of the eco-system.

Physico-chemical features of water in Barna reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average
Temp. (°C)	31.6	30.0	25.0	25.0	27.9
Transp. (cm)	305	75	120	122	156
pH	7.6	7.3	7.4	7.4	7.4
Sp. cond (µS/cm)	166	148	156	156	157
TDS (mg/l)	108	96	101	101	102
DO (mg/l)	7.0	7.0	9.2	9.8	8.3
Carbonate(mg/l)	10.0	4.0	6.0	8.0	7.0
Bicarbonate(mg/l)	80	74	70	70	74
TA (mg/l)	90	78	76	78	81
TH (mg/l)	35	30	30	36	33
Ca^{+2} (mg/l)	9.61	8.02	8.02	9.61	8.82
Mg^{+2} (mg/l)	2.67	2.42	2.42	2.91	2.61
Cl^{-1} (mg/l)	21.30	14.20	14.20	17.04	16.69
NO_3-N (µg/l)	15	48	65	40	42
PO_4-P (µg/l)	10	25	28	20	20
Total-P (µg/l)	38	92	120	76	82
SiO_2-Si (mg/l)	1.2	1.4	1.6	1.4	1.4

Amongst other physico-chemical factors, wind action is the most vital one as the wind-induced turbulence churns the water, breaking thermal stratification. This facilitates mixing of nutrients specially in this reservoir with low mean depth and flat basin.

Water reaction is one of the most important chemical factors as good fish crops are usually produced in water just in the alkaline side (pH 7.0 & 8.0). pH above 10.0 and below 4.0 has a detrimental effect. In Barna, water reaction was near neutral in monsoon and post-monsoons (7.3-7.4) with little increase in pre-monsoon (pH 7.6) period - a very productive criterian for this water body. Free CO_2 remained absent year round in surface waters but it was present to the extent of 2-3 mg/l at the bottom (18m) during pre-monsoon months resulted from decomposition of bottom organic load, signifying moderate tropholytic activities at the bottom.

Dissolved oxygen (DO), the prime important critical factor in natural waters both as regulator of metabolic processes of plant and animal community and as an indicator of water health condition was in the range 7.0-9.8 mg/l in this reservoir. A higher value of DO in winter is due to low water temperature in this season. A good productive reservoir should have DO concentration more than 5 mg/l.

Moderate presence of electrolytes in this reservoir was noticed as seen from the values of sp. conductivity (148-166 µS/cm, mean: 157). Measurements of dissolved solids indicate the total concentration of dissolved ions having a wide bearing on productivity. Total dissolved solids (TDS) was in the range 96-108 mg/l, representing moderate production in this reservoir. A declining trend of both specific conductance and TDS was observed from surface to bottom.

Alkalinity is basically caused by carbonates and bicarbonates of calcium and magnesium, Ca being the dominant constituent. Along with these, dissolved CO_2 in water forms an equilibrium system which is of prime importance in determining productivity of reservoir. Natural waters containing 40 mg/l or more total alkalinity (TA) are more productive, the greater productivity of waters of higher alkalinity is not due to alkalinity directly, but in turn due to the availability of phosphorus and other nutrients with total alkalinity. Presence of carbonate was to the tune of 4-10 mg/l in Barna while prime contribution in total alkalinity was made by bicarbonate in the range 70-80 mg/l. Thus, a moderate concentration of total alkalinity (76-90 mg/l, mean: 81) was noticed in this reservoir with lower values in monsoons due to dilution effect.

Total hardness (TH) refers to the concentration of divalent metal ions in water, expressed as equivalent of $CaCO_3$, which is usually related to total alkalinity as the anions of alkalinity and cations of hardness are normally derived from the solution of carbonate minerals. Ecosystems having moderate hard water (60-120 mg/l, TH) to hard (120-180 mg/l, TH) water are more productive as the total hardness reflects the trends of Ca and Mg in water bodies. Ca and Mg play an important role in antagonising the toxic effect of various ions and in neutralising the excess acid produced. Barna is a soft water reservoir as reflected through its total hardness values in different seasons (30-36 mg/l) and never exceeded the corresponding values of total alkalinity. This low value in total hardness indicating poor buffering capacity of this reservoir is more phenomenal in cases of extreme fluctuations in water depth on productivity. Presence of Ca was low (8.02 to 9.61 mg/l) as also in the case of Mg (2.42-2.91 mg/l). A declining trend of total hardness was observed from surface to bottom, though not significant.

The reservoir experienced more chloride content (21.30 mg/l) in pre-monsoon as compared to following seasons (14.20-17.04 mg/l). From the chloride values, it could be inferred that the reservoir is free from local pollution.

Nutrient status of water

The role and importance of nitrogen and phosphorus in aquatic productivity have been recognised and widely studied. Nitrogen, a major constituent of protein occupies a predominant place in aquatic system. In general, phytoplankton utilize inorganic-N in NO_3^- and NH_4^+ forms and some zooplankton utilize particular organic nitrogen. Owing to its quicker utilization by plankters, higher solubility, leaching loss and denitrification, NO_3 - N is a limiting factor in Indian reservoirs. In Barna, nitrate-N (µg/l) was encountered in the range 15-65 (mean: 42), with maximum noticed in post- monsoons being loaded with allochthonous inputs carried from the catchment which was the prime nutrient source of this reservoir apart from autochthonous source. The catchment of Barna is mostly covered with denuded low-fertile forestland in association with some moderately fertile cropland. Total-N content was also low to the extent of (52-350 µg/l) in sub-surface waters.

Though, a relatively minor constituent, phosphorus is often considered to be the most critical single element in maintaining aquatic productivity. It helps in assimilation of nitrogen into cellular matter. The extremely reactive nature, quick turn over and recycling of phosphorus make it a limiting factor in Indian reservoirs. Phosphate-P also was very meagre like other M.P. reservoirs ranging from (10-28 µg/l). But total-P was substantially present specially during post-monsoon at 120 µg/l with an overall range 36-120 µg/l signifying that the reservoir is under oligotrophic to mesotrophic category.

Silicate-Si, the basic constituent of diatoms was very low (1.2-1.6 mg/l) in Barna with a little increase during monsoons might be due to its utilization by Bacillariophyceae.

Stratification

Stratification in reservoirs is a subject of much discussion because it exerts influence not only in the reservoir itself but also affects the stream flowing below the dam.

Thermal stratification results in chemical stratification and mostly occurs in pre-monsoon months and occasionally in post-monsoon periods in tropical Indian reservoirs. Unlike temperate lakes, thermal stratification is not well marked in peninsular Indian reservoirs of lower latitudes. It was true with M.P. reservoirs also. Distribution of physico-chemical parameters in vertical profile revealed homogeneity in water temperature, DO, pH, TA, TH along the water column in most part of the year barring pre-monsoon months. During pre-monsoon, stable thermocline with clear demarcation of meta- and hypolimnion was observed with a fall of hypolimnion temperature to the extent of 3.5°C from the surface. Clinograde distribution of oxygen was observed with drastic fall in DO at hypolimnion to the extent of 4.8 mg/l especially during pre-monsoon months but rarely occurred anoxic bottom in this reservoir.

Biotic communities

Plankton

The quantitative abundance of plankton in Barna varied from 211 to 704 u/l (0.70 - 1.41 ml/m^3). Plankton showed a distinct winter pulse which is attributed to higher monsoon inflow responsible for increasing the plankton production. The summer pulse was of lower magnitude. Phytoplankton (84.1%) represented by Bacillariophyceae (44.5 %) 5 species, Chlorophyceae (17.7 %) 8 species and Myxophyceae (21.9%) 7 species was predominant. The occurrence of

zooplankton (15.9%) was poor. It was represented by Copepoda (7.9 %) 2 species, Cladocera (3.0 %) 4 species and Rotifera (5.0%) 12 species. The plankton forms encountered from this reservoir are given below:

Plankton of Barna reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Dinophyceae	Myxophyceae
Mastogloia danseii	*Cerasterias irregulare*	*Ceratium hirundinella*	*Amphithrix janthina*
Navicula	*Closterium*	*Gonyaulax apiculata*	*Anabaena*
Nitzschia	*Eudorina*		*Anacystis cyanea*
Rhopalodia gibba	*Genicularia*		*Coelosphaerium*
Synedra ulna	*Gonatozygon*		*Oscillatoria tenuis*
	Hormidium subtile		*Phormidium*
	Pediastrum duplex		*Stichosiphon*
	Pediastrum simplex		

Zooplankton

Cladocera	Copepoda	Protozoa	Rotifera
Alona	*Cyclops*	*Difflugia lobostoma*	*Anuraeopsis*
Bosminopsis dietersi	*Diaptomus*	*Difflugia urceolata*	*Brachionus angularis*
Ceriodaphnia cornuta	Nauplii		*Brachionus bidentata*
Chydorus ovalis			*Brachionus havanaensis*
			Brachionus quadridentata
			Filinia longiseta
			Hexarthra mira
			Keratella valga
			Polyarthra
			Pompholyx sulcata
			Trichocerca longiseta
			Trichocerca multicrinis

Macro-benthos

The density of macro-benthic population ranged from 347 to 935 nos/m^2. Molluscs formed the main bulk of it. Dipterans were more numerically. The total macro-benthos was represented by Gastropods (42.6%), Bivalves (12.5%), Dipterans (36.5%) and Odonates (8.4%). The following macro-benthic forms were recorded during the course of this study :

Gastropods : *Thiara, Bellamya, Gyraulus*
Bivalves : *Corbicula, Parreysia*
Dipterans : *Chironomus, Chaoborus*
Odonates : *Anax*

Periphyton

The density of periphytic community in Barna fluctuated between 441 and 1785 u/cm^2 (0.07-0.15 ml/cm^2). Like plankton, periphyton also indicated a very prominent winter pulse in December and a comparatively low summer pulse. Diatoms (75.6%) were predominant followed by Green algae (22.1%), Blue-green algae (1.5%) and Desmids (0.8%). All the periphytic forms are shown below:

Periphyton of Barna reservoir

Bacillariophyceae	Chlorophyceae	Desmidiaceae	Myxophyceae
Amphora	*Binuclearia tatrana*	*Cosmarium*	*Anabaena*
Asterionella	*Cladophora*	*Staurastrum*	*Phormidium*
Cymbella	*Closterium*		
Diatomella	*Gonatozygon*		
Gomphonema	*Genicularia*		
Navicula	*Hormidium*		
Nitzschia	*Zygnemopsis*		
Rhopalodia			
Synedra			
Tabellaria			

Macrophytes

The observations revealed that the saddle zone of Barna reservoir was richer in macrophytes. The reservoir exhibited good growth of macrophytes during January-March '99 (3261 g/m^2). The occurrence of *Vallisneria, Hydrilla, Ceratophyllum, Potamogeton, Chara* and *Najas* was observed in this reservoir.

Fish yield and catch composition

Barna reservoir is under the control of Madhya Pradesh Matsya Mahasangh. For commercial exploitation, royalty and contract systems were practiced by the Federation.

The fish yield of Barna varied from 16.9 to 152.2 t. It was low during 1988-89 to 1991-92 (16.9 - 80.0 t) i.e. 3.5-16.7 kg/ha and increased from 1992-93 to 1997-98 (102.1-152.2 t) being 21.3 - 31.8 kg/ha. The increase in yield was due to enhanced fishing effort and stocking. Major carps (62-93%) formed the main fishery of the reservoir with the dominance of *C. catla* (34-77%). It merits mention that catla fishery is declining from 1994 onwards with the improvement in *L. rohita* and *C. mrigala* catch. The exploitation of minnows was started from 1994-95 (7.5 %) only. During last five years (1996-97 to 2000-01), major carps went down to 45.7% comprising *C. catla* (17.2%), *L. rohita* (14.6%), *C. mrigala* (13.4%) and *T. tor* (0.5%). The contribution of local major was 14.8%, local minor 21.7% and minnows 17.8%.

Local major	Local minor
W. attu, A. aor, A. seenghala, N. chitala, Mastacembelus sp., Channa sp. and *L. calbasu* (>0.5 kg)	*N. notopterus, L. gonius, L. bata, C. reba, Mystus sp.* and *L. calbasu* (<0.5 kg)

Fishing effort

The fishing effort data of Barna for 1998-99 indicated that 30 fishing units were engaged in the commercial fishing every day. One fishing unit comprises one boat with two fishermen and 20 kg of nets. The catch per unit of effort (CPUE) was calculated to be 15.3 kg. The effort was more during 1996-97 (50 units/day) and 1997-98 (40 units/day) utilizing greater fishing span of 285 and 250 days respectively. It yielded higher fish production (152 and 141 t) during this period. Later, with the decrease in efforts, the production also declined considerably and went down to 19.1 t against 90 fishing days (17 units/day) only during 1999-2000.

Stocking

The reservoir is being stocked adequately @ 300 fingerlings/ha/y with main attention on Catla. The retrieval of major carps in relation to stocking was found to be 3-5 % only. In view of good concentration of molluscs, insects and macrophytes, mahseer may be included in the stocking programme of Barna. The ecological conditions also support the stocking of grass carp in this reservoir.

Primary production

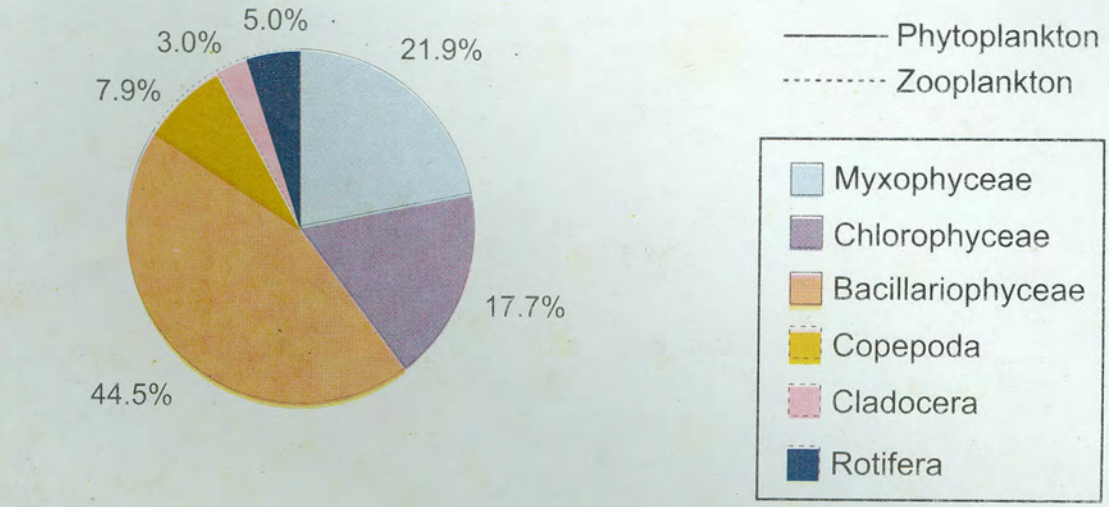
The gross (GPP) as well as net (NPP) primary production ($mgC/m^3/h$) showed wide seasonality in this reservoir. Being a large reservoir, the average value of GPP was poor (74.4) as compared to other reservoirs under this study having an overall range 46.9 to 93.8 mg. The assimilation efficiency (A.E) was very poor in monsoon (28.6%), the average being 48.9%. Community respiration (CR, $mgC/m^3/h$)) also showed clear seasonality with maximum value in post-monsoon (31.3 mg) with an average of 25.5 mg. P:R ratio did not vary widely with the seasons in the range (2.6-3.1) signifying autotrophic mode of production in this reservoir.

Productivity status

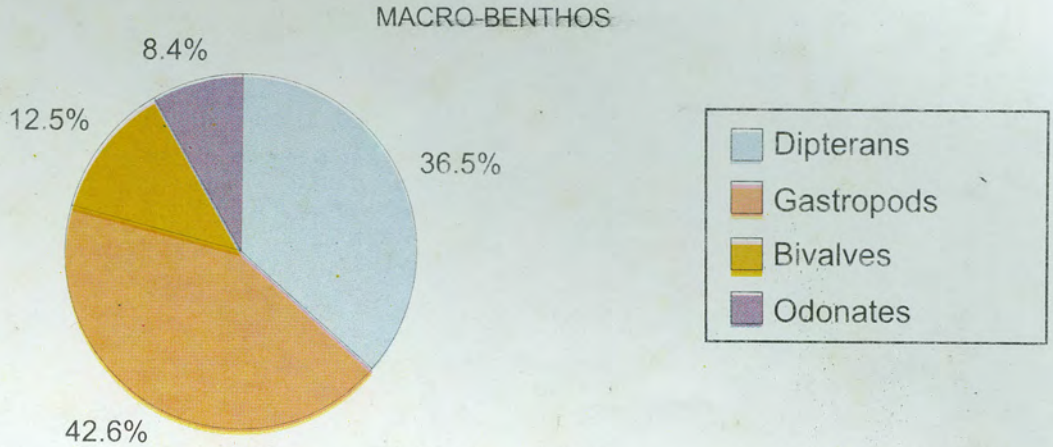
The bigger reservoir area coupled with poor plankton, sediment and water characteristics with moderate C/A (15), Barna may be categorised as a low to medium productive reservoir. Out of different models used for estimation of fish production potential of Indian reservoirs, phytoplankton primary production (Trophodynamic model) is widely accepted. The gross primary production was 74.4 $mgC/m^3/h$ and assuming a very judicial conversion efficiency of 0.2% GP, the **'targeted potential fish yield' (TPFY)** of Barna was estimated at 70 kg/ha/y. The actual potential of any reservoir could be much more than the TPFY because in calculating TPFY, only the inputs from autochthonous source are taken into consideration. Achieving TPFY is more luring to the fishery managers which could be obtained through sustainable management policies. The present maximum production of this reservoir was 32 kg/ha/y. Thus, the gap between present fish yield and TPFY could easily be mitigated and at least 60-70% of TPFY could be realised following suitable stocking norms and other management options.

Quality composition of biotic communities of Barna reservoir (1998-1999)

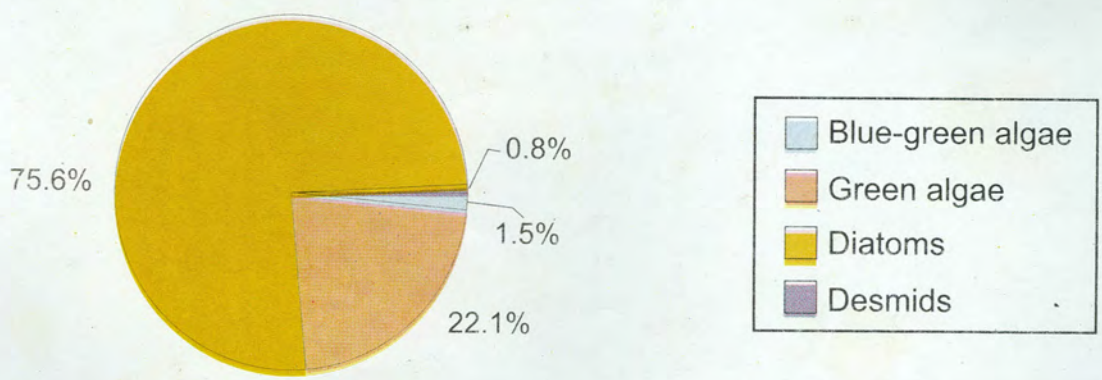
PLANKTON



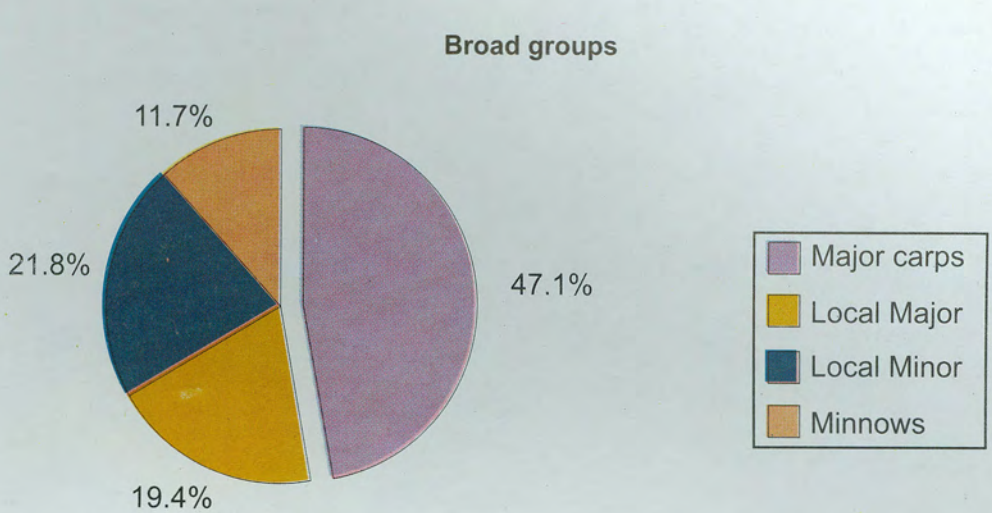
MACRO-BENTHOS

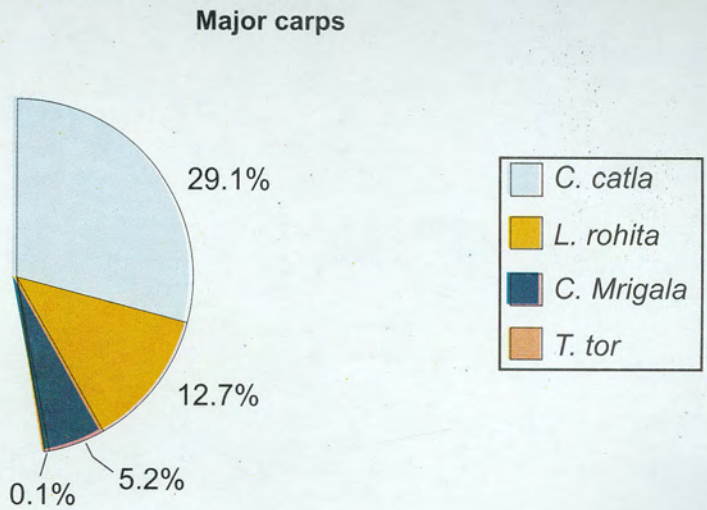


PERIPHYTON

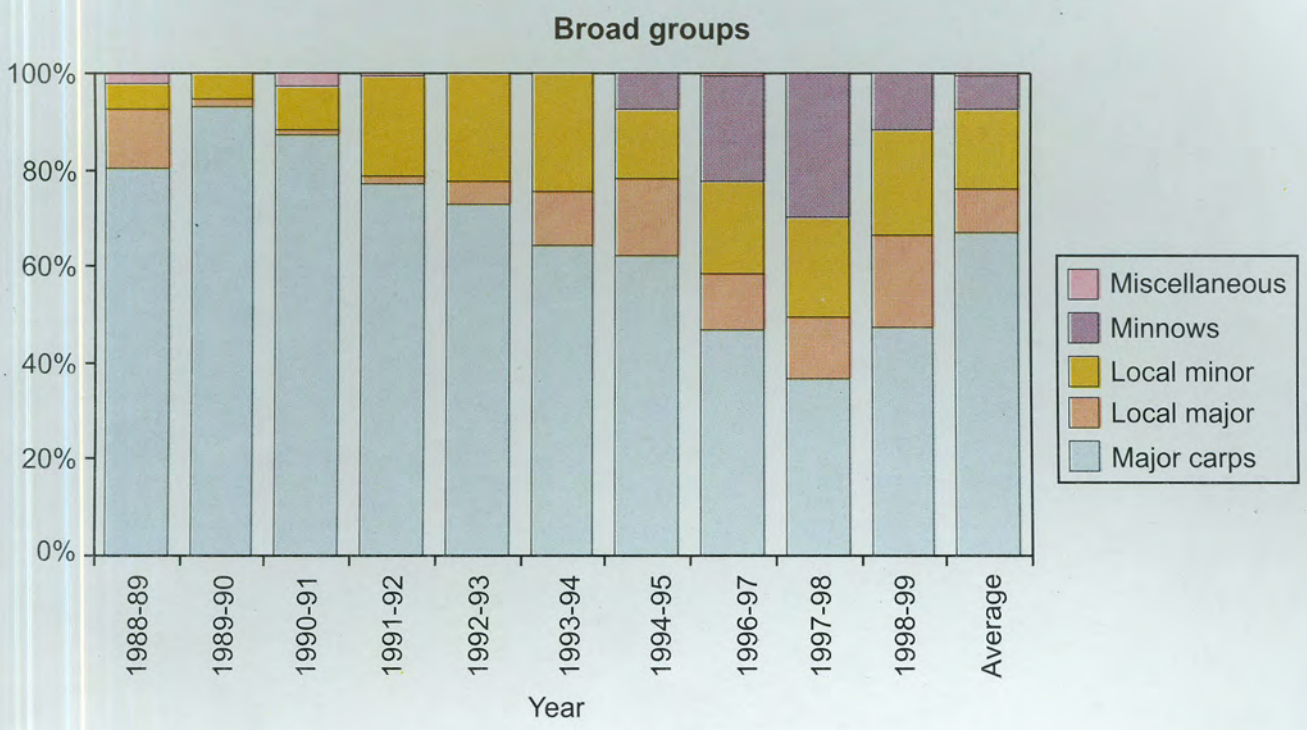


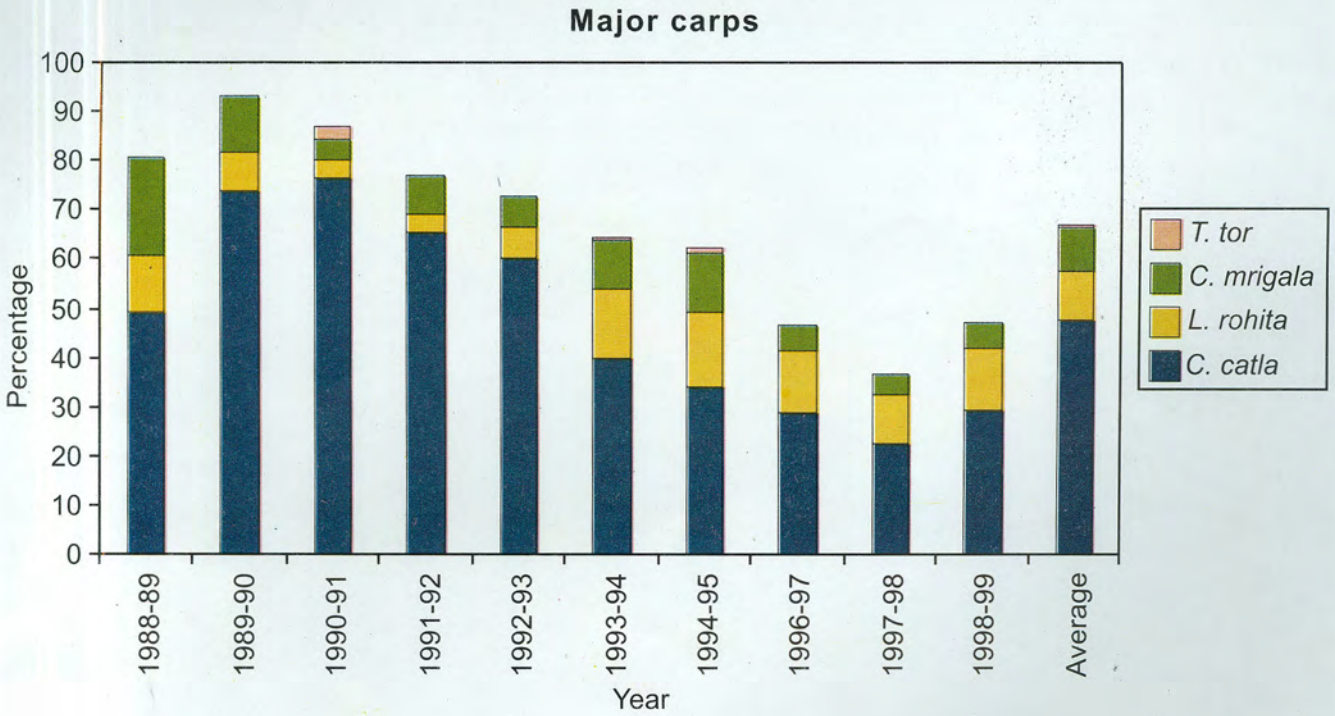
Fish catch composition (%) of Barna reservoir (1998-99)





Fish catch composition (%) of Barna reservoir (1988-89 to 1998-99)





A view of Barna reservoir

A haul of fish catch of Barna

DAHOD RESERVOIR

Dahod is an irrigation project near village Dahod in Goharganj Tehsil of district Raisen. A fair weather road of 11 km leads from N.H. 12 to the dam site. It is about 60 km from Hoshangabad. It is an earthen dam. The main river is Bangna (local nalla) which has a total length of about 15 km and joins river Betwa at Nayapura near Mandideep. Ecological studies of this reservoir were undertaken during 1998-99.

Salient morphometric and hydrographic features

Location (District)	Raisen
Year of construction	1958
Latitude	23° 2'N
Longitude	77° 29' 30" E
Basin	Betwa
FRL (m)	459.94
LSL (m)	453.85
Maximum depth (m)	9.2
Mean depth (m)	3.4
Water spread at FRL (ha) A	820
Catchment area (km^2) C	51.79
Catchment to reservoir area (C/A)	6
Productive area (ha)	460
Gross capacity at FRL (10^6 m^3)	27.75
Shore line (km)	37.5
Shore development	3.7
Volume development	1.11
Av. annual rainfall (mm)	1145
Purpose	Irrigation

Sediment characteristics

Soil was sandy-clay in nature comprising 65% sand, 11% silt and 24% clay. More clay content was noticed in littoral soil. Soil reaction was slightly acidic (pH 6.0). Sp. conductance was in the range 0.155 to 0.230 mS/cm. Organic carbon content was moderate, registering a high of 1.38% in winter to a low of 1.07% in monsoon (mean : 1.20%). Littoral soil exhibited more organic carbon (1.48%) due to heavy infestation of macrophytes predominantly in marginal areas of the reservoir. Total-N content was low (0.06%) and did not vary widely with seasons. C/N ratio, a predictor of productivity was around 20, representing a balanced rate of both mineralisation and immobilisation. Amongst available nutrients, phosphate-P was a limiting factor (0.60 mg/100 g) due to moderate acidic nature of basin soil. On the other hand, in spite of its quicker utilization by aquatic macrophytes, available-N (mg/100 g) was moderately present to the tune of 28.57 to 35.62 (mean: 31.64). Littoral soil showed slightly lower concentration of it (28.45 mg/100 g).

Sediment characteristics of Dahod reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average (Profundal)	Average (Littoral)
Sand (%)	68	60	65	67	65	58
Silt (%)	8	15	10	10	11	12
Clay (%)	24	25	25	23	24	30
pH	6.2	6.4	5.8	5.7	6.0	5.6
Sp. cond (mS/cm)	0.230	0.187	0.164	0.155	0.184	0.158
Org. C (%)	1.18	1.07	1.20	1.38	1.20	1.48
Total-N (%)	0.065	0.054	0.060	0.061	0.06	0.074
C/N	18	20	20	22	20	20
Avail-N (mg/100g)	28.57	30.02	35.62	32.35	31.64	28.45
Avail-P (mg/100g)	0.28	0.80	0.92	0.40	0.60	0.46
Free $CaCO_3$ (%)	0.98	1.02	0.85	0.80	0.91	0.78

Physico-chemical features of water

Water temperature fluctuated sinusoidally (22.0-30.0°C, mean : 26.5°C). Euphotic zone was extended phenomenally more after cessation of monsoon rains and attained a maximum value of 5 m in winter facilitating penetration of sunlight upto bottom - a very productive feature of this water body. Secchi depth was the lowest (60 cm) in monsoons. It was also low in pre-monsoon (74 cm) primarily because of low depth of water coupled with strong wind action which churned the whole water body to a great extent. Water reaction was moderately alkaline (pH 8.8). Specific conductance was in the range 112-132 µS/cm, representing moderate presence of soluble ions in water phase.

Physico-chemical features of water of Dahod reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average
Temp. (°C)	28.0	30.0	22.0	26.0	26.5
Transp. (cm)	74	60	211	214	140
pH	8.4	8.8	9.0	8.9	8.8
Sp. cond (µS/cm)	132	124	112	126	124
TDS (mg/l)	86	81	73	82	81
DO (mg/l)	9.6	8.2	12.0	11.0	10.2
Free CO_2 (mg/l)	0	4.0	3.0	0	0
Carbonate (mg/l)	6.0	0	0	2.0	0
Bicarbonate(mg/l)	108	104	90	80	94
TA (mg/l)	114	104	90	82	96
TH (mg/l)	47	40	38	42	42
Ca^{+2} (mg/l)	16.03	12.82	12.82	12.82	13.62
Mg^{+2} (mg/l)	1.68	1.93	1.45	2.42	1.87
Cl^{-1} (mg/l)	15.0	14.0	14.0	15.0	14.5
NO_3-N (µg/l)	4	38	40	12	24
PO_4-P (µg/l)	4	4	8	8	6
Total-P (µg/l)	14	22	36	34	27
SiO_2-Si (mg/l)	0.40	1.20	0.80	0.60	0.75

Amongst dissolved gases, DO was fairly rich especially during pre-monsoon and winter (11-12 mg/l). High DO level in these seasons was primarily due to low temperature and higher rate of photosynthesis predominantly by macrophytes. Presence of free CO_2 was only during monsoons (3-4 mg/l). Total alkalinity, mostly contributed by bicarbonates was ranging from 82 mg/l in winter to 114 mg/l in pre-monsoon period. Total hardness was comparatively lower than corresponding total alkalinity irrespective of seasons and ranged between 38 and 47 mg/l (mean: 42). Ca^{+2} content was moderate (12.82-16.03 mg/l) while Mg^{+2} ions were very low in concentration (1.45-2.42 mg/l). Presence of chloride also was moderate (14.0-15.0 mg/l) suggesting that the water body is free from local pollution.

Nutrient status of water

Amongst dissolved nutrients, phosphate-P was a limiting factor due to its non-availability from basin soil to water phase. Available-N also was low in winter (12 mg/l) and pre-monsoon (4 mg/l) and more in monsoons (38-40 mg/l). Total-P was in the range 14-36 mg/l in this water body. Silicate silicon was very poor in most occasions (0.4-0.8 mg/l) and occurred in slightly more concentration during monsoon (1.2 mg/l).

Biotic communities

Plankton

Dahod reservoir was rich in plankton with greater species diversity and it ranged from 873 u/l (2.11 ml/m^3) to 6366 u/l (7.04 ml/m^3). It exhibited two peaks, a very distinct summer pulse of high magnitude (6366 u/l) and winter pulse of lower concentration (3676 u/l). The phytoplankton (94.3%) was predominant with poor zooplankton (5.7%). Among phytoplankton, Myxophyceae (76.8%) formed the mainstay of plankton community with poor occurrence of Bacillariophyceae (13.7%), Chlorophyceae (2.6%) and Dinophyceae (1.2%). Zooplankton was represented by Cladocera (3.4%), Copepoda (2.0%) and Rotifera (0.3%). In all 42 plankton forms of phyto (21) and zooplankton (21) were recorded from this reservoir as shown in the following table.

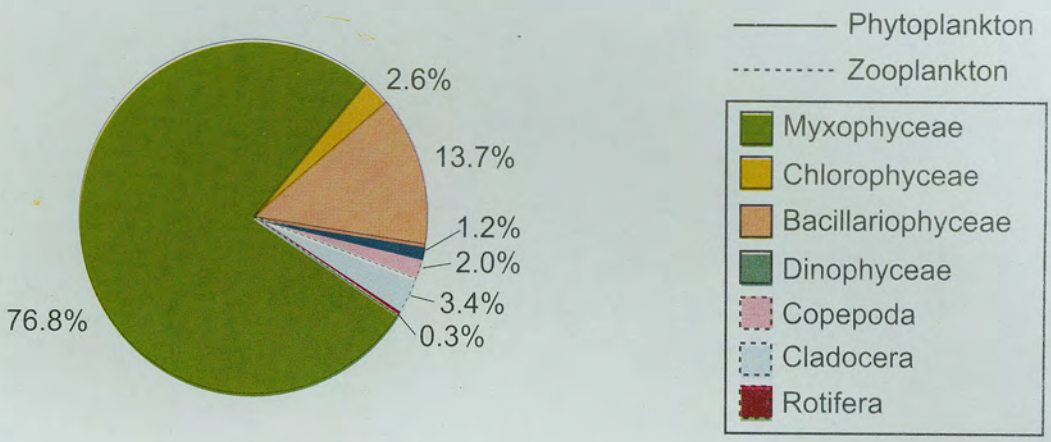
Plankton of Dahod reservoir

Phytoplankton

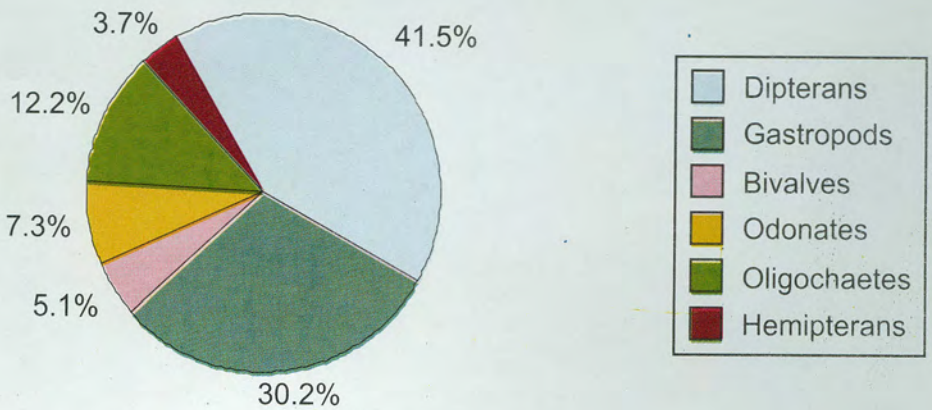
Bacillariophyceae	Chlorophyceae	Dinophyceae	Myxophyceae
Bacillaria paradoxa	*Ankistrodesmus*	*Gonyaulax apiculata*	*Anacystis cyanea*
Gomphonema	*Closterium*		*Anacystis incerta*
Navicula	*Eudorina elegans*		*Oscillatoria*
Nitzschia	*Gonatozygon*		*Spirulina*
Rhopalodia gibba	*Hormidium*		*Stichosiphon*
Surirella	*Pediastrum simplex*		
Synedra ulna	*Spirogyra varians*		
Tabellaria fenestrata			

Quality composition of biotic communities of Dahod reservoir (1998-1999)

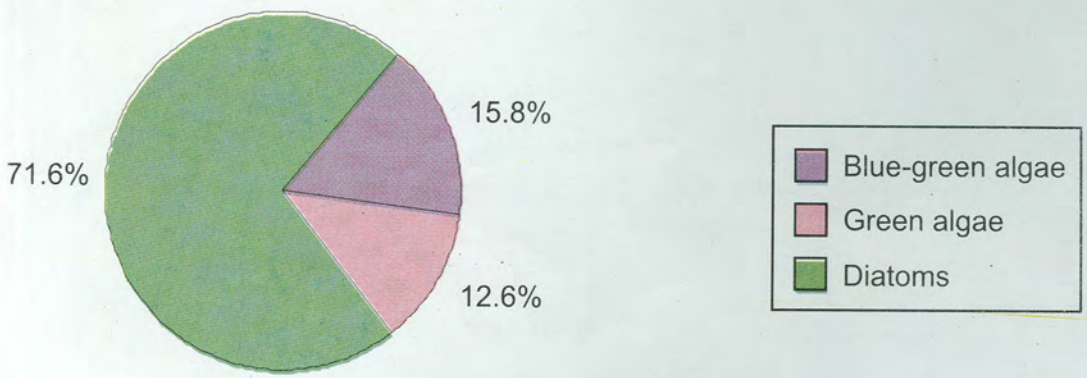
PLANKTON



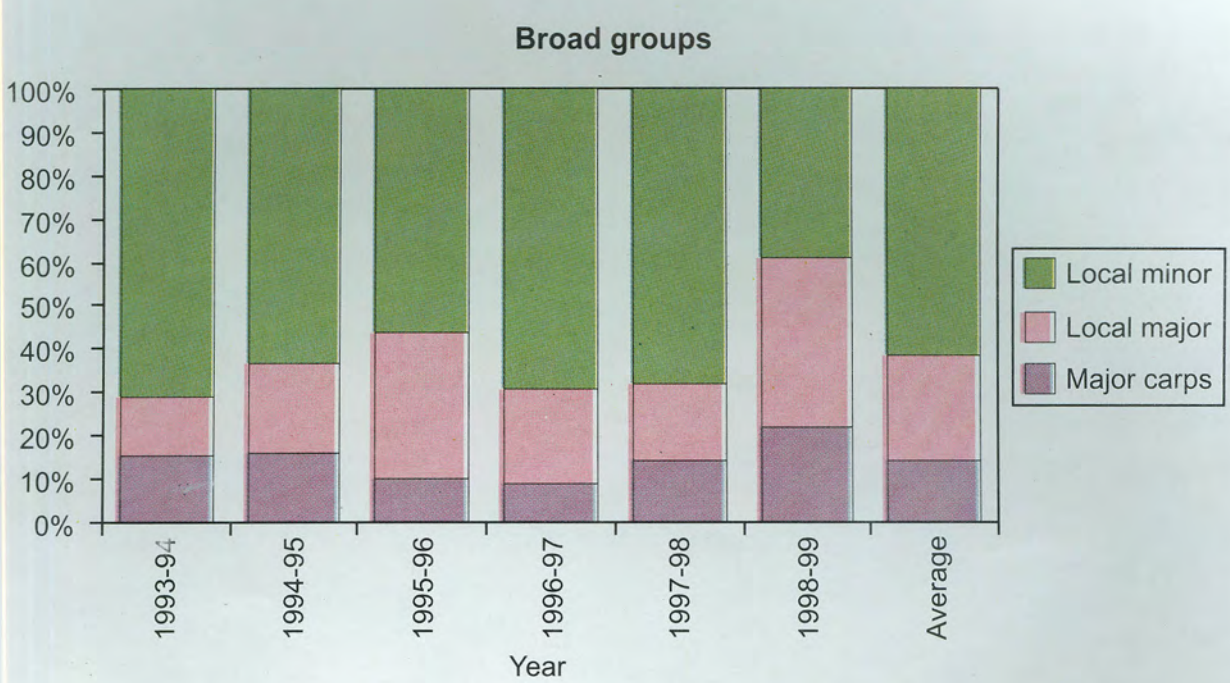
MACRO-BENTHOS

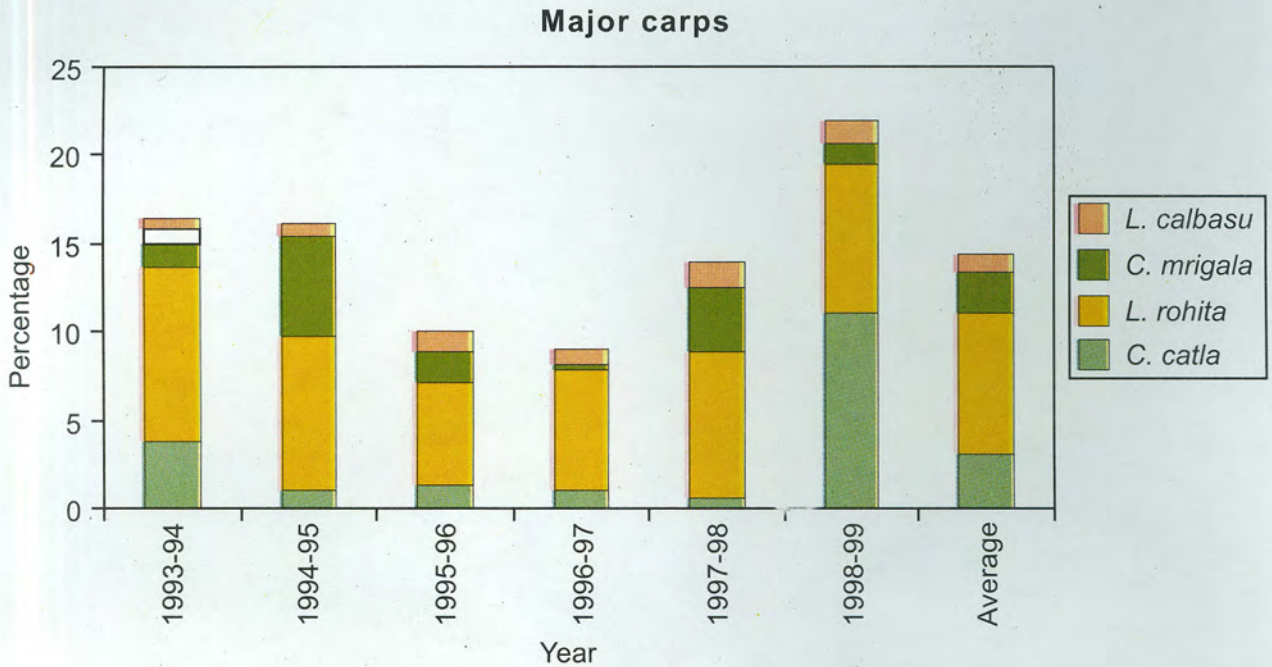


PERIPHYTON

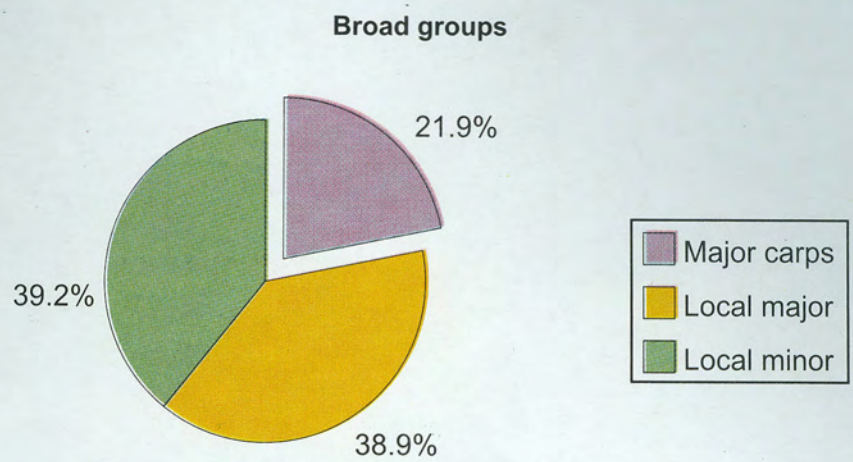


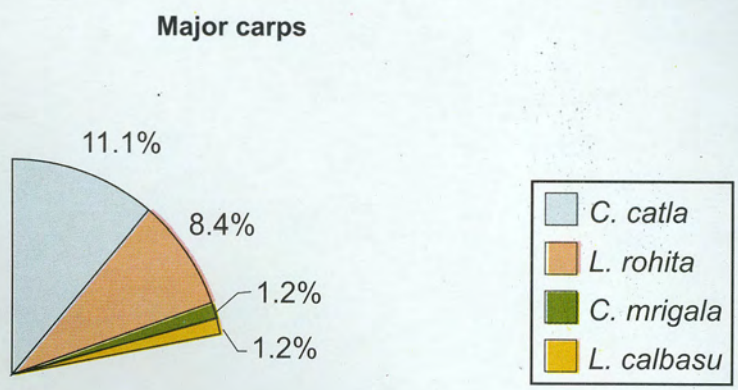
Fish catch composition (%) of Dahod reservoir (1993-94 to 1998-99)





Fish catch composition (%) of Dahod reservoir (1998-99)

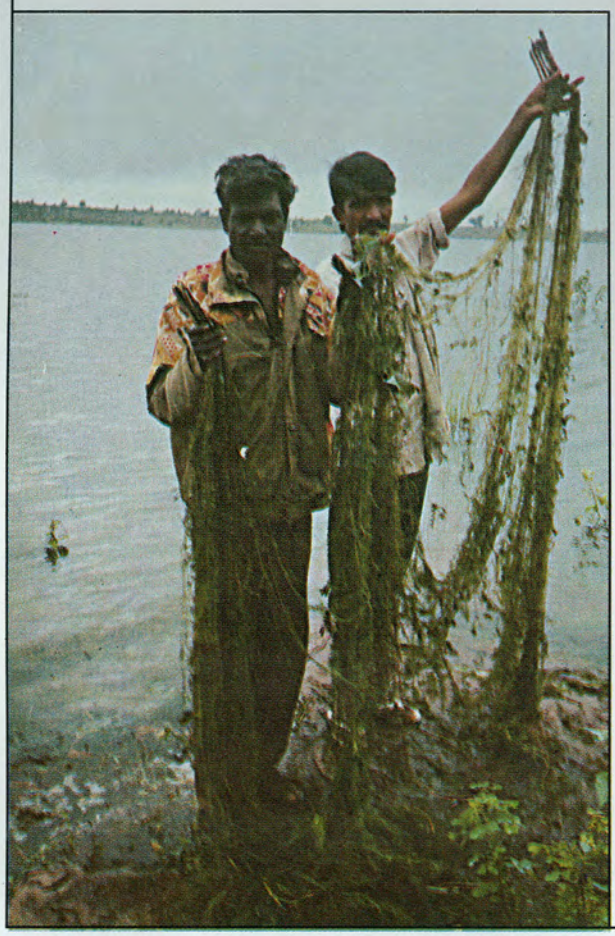




A view of Dahod reservoir

Fish catch of Dahod

Fishing implements in Dahod



Macrophyte infestation in Dahod

Zooplankton

Cladocera	Copepoda	Ostracoda	Protozoa	Rotifera
Alonella	*Cyclops*	*Cypris subglobosa*	*Difflugia urceolata*	*Brachionus angularis*
Bosmina longirostris	*Diaptomus*			*Brachionus bidentata*
Bosminopsis dietersi	Nauplii			*Brachionus havanaensis*
Ceriodaphnia cornuta				*Brachionus quadridentata*
Chydorus ovalis				*Horaella brehmi*
Diaphanosoma				*Keratella cochlearis*
				Keratella valga
				Pompholyx sulcata
				Proales decipiens
				Synchaeta pectinata
				Wigrella depressa

Macro-benthos

Macro-benthic population of Dahod varied from 912 to 1652 nos/m^2. Dipterans (41.5%) were most important followed by Gastropods (30.2%), Oligochaetes (12.2%), Odonates (7.3%), Bivalves (5.1%) and Hemipterans (3.7%). Macro-benthos also showed rich diversity of groups as shown below:

Gastropods	*Bellamya Thiara, Gyraulus*
Bivalves	*Corbicula, Parreysia*
Dipterans	*Chironomus, Chaoborus*
Odonates	*Anax*
Oligochaetes	*Lumbriculus*
Hemipterans	*Laccotrephes ruber, Lethocerus indicus*

Periphyton

Periphytic density of Dahod varied from 336 u/cm^2 (0.07 ml/cm^2) to 2925 u/cm^2 (0.25 ml/cm^2). The winter pulse (2925 u/cm^2) observed in December was significant. The main bulk of periphyton was formed by Diatoms (71.6%). The occurrence of Blue-green algae (15.8%) and Green algae (12.6%) was also observed. The recorded forms are presented below.

Periphyton of Dahod reservoir

Bacillariophyceae	Chlorophyceae	Myxophyceae
Cocconeis	*Hormidium*	*Amphithrix*
Cymbella	*Phacus*	*Anabaena*
Gomphonema	*Volvox*	*Anacystis*
Navicula		*Phormidium*
Nitzschia		*Stichosiphon*
Opephora martyi		
Rhopalodia		
Surirella		
Synedra		

Macrophytes

Dahod has a dense infestation of submerged macrophytes like *Hydrilla, Vallisneria spiralis, Ceratophyllum, Najas, Potamogeton pectinatus, Potamogeton crispus, Potamogeton nodosus.* These macrophytes are available throughout the reservoir with greater concentration in the littoral zone. The concentration of macrophytes during the period of study varied from 3043 to 5217 g/m^2. The thick growth of macrophytes poses problems in the operation of fishing nets. The egg collection is also not possible in Dahod due to this menace.

Fish catch and catch composition

Dahod reservoir is under the control of Madhya Pradesh Fisheries Department. The fishing system is on royalty basis, being given to the Fisherman Co-operative Societies and the Fisherman Groups.

The fish yield ranged from 9.1 t (1993-94) to 16.5 t (1997-98). An annual target of production is set by the State Fisheries Department which is achieved every year. These targets appear to be very low and as such the calculation of production/ha may not give the correct picture in this case.

In the catch composition, Local minor (65.4%) was the most important with the prevalence of *N. notopterus* and *X. cancila*. The other species in this group were *P. sarana, C. nama, P. ranga, C. laubuca, S. bacaila* etc. Local major (21.7%) group represented by *W. attu, A. aor, A. seenghala, Channa* sp., *O. pabda, L. gonius, M. armatus, M. pancalus, C. batrachus, H. fossilis* was second in order of importance. Major carps contributed 12.9% with dominance of *L. rohita* (7.8%).

In February '99 the signs of ulcerative disease were observed in *N. notopterus* and *Mastacembelus* spp. Multiple inflammatory red spots were seen on the body. Some specimens of *Mastacembelus* also exhibited ulcers in abdomen and peduncle regions.

Fishing effort

Based on the fishing effort data of Dahod reservoir for 1998-99, the catch per unit of effort (CPUE) was worked out at 6.4 kg with 15 fishing units/day. One unit comprises one boat, one fisherman and 10 kg of nets.

Stocking

The stocking of the reservoir is undertaken every year with sufficient seed of major carps (1.8-7.0 lakh fingerlings/y) with greater emphasis on mrigal and rohu. The retrieval of major carps in relation to stocking is very poor (0.2%). The heavy infestation of macrophytes in Dahod warrants introduction of grass carp with higher rate to control the luxuriant growth of submerged weeds. The reservoir may be stocked @ 600 fingerlings /ha/y in the ratio 2 catla : 2 rohu : 2 mrigal : 4 grass carp (100-125mm).

Primary production

GPP (mgC/m^3/h) was significantly more during summer (130.6) followed by post-monsoon (117.2) and the low value was obtained in monsoon (76.2). The NPP (mgC/m^3/h) also was very

poor during monsoon (46.3), the average being at 73.2 mg. The assimilation efficiency was very moderate in the range 59.2-70.3% having low impact of seasonality, signifying a good productive reservoir. Community respiration ($mgC/m^3/h$) was in the moderate range with little seasonal variation (31.9 - 39.8). P : R ratio also did not vary greatly with seasons (2.5-3.4) indicating autotrophic dominance of production in this reservoir.

Productivity status

Dahod is in the marginal category of small and medium reservoir with low C/A ratio (6). The catchment characteristics also showed that the catchment area was not so fertile as to support the productivity of this reservoir. But, considering the phytoplankton primary production as well as assimilation efficiency, the reservoir could be categorised as medium productive one in view of the heavy infestation of macrophytes predominantly in littoral areas getting reflected into productivity through detrital chain. So, an orthodox consideration of 0.4% GP would give an estimate of TPFY at 285 kg/ha/y. The present fish harvest from this reservoir is around 35-40 kg/ha which could be enhanced at least two to three folds following suitable management norms.

Plausible management guidelines

- The annual target of fish production as set by the State Fisheries Department every year, is very low as against the production potential of this reservoir. This target needs to be raised to 50 t/y at least.

- The poor retrieval of major carps (0.2%) indicated that the stocking has no desirable impact on major carp fishery. In view of the prevalence of indigenous species, the stocking rate of major carps could be reduced in this reservoir.

- The breeding of major carps is taking place in Dahod but the survival is very poor. The collection of eggs is not possible due to the heavy infestation of hydrophytes. Dahod has a dense infestation of submerged macrophytes which also pose serious problems in the smooth operation of fishing gears in the reservoir. The introduction of grass carp may pay dividends in Dahod. Besides controlling the luxuriant growth of macrophytes, it would increase the production also. A higher stocking rate of grass carp (40%) is required in this reservoir.

- The hilly catchment and the confluence of three local nallas viz., Imalia, Javara and Bagwani at the lotic zone facilitate successful Wet-bundh breeding during monsoons in this reservoir. The major carps ascend to Bagwani nalla during monsoons for breeding where the breeders are caught and killed by the poachers. The breeding grounds need to be protected.

- The reclamation of tree trunks from the reservoir is necessary for smooth operation of fishing gears.

SAMPNA RESERVOIR

The construction of Sampna dam was undertaken in 1953 and completed in 1958 during first five year plan to provide irrigation to 18 villages of district Betul. The reservoir site is approachable from Betul- Nagpur road and is about 15 km from Betul. It is an earthen dam. The catchment area is mostly hilly and densely forested. The hill slopes are steep and the main Sampna river flows along a cut-up valley and number of ravines forming its feeder. Sampna river meets river Manchna to join river Tawa - the tributary of river Narmada. This reservoir was studied during 1998-99.

Salient morphometric and hydrographic features

Location (District)	Betul
Year of construction	1958
River	Sampna
Basin	Narmada
FTL (m)	694.10
LSL (m)	686.10
Maximum depth (m)	11.4
Mean depth (m)	6.4
Water spread at FTL (ha) A	262
Catchment area (km^2)	44.75
Catchment to reservoir area (C/A)	17
Gross capacity at FRL (10^6 m^3)	16.92
Shore line (km)	8.0
Shore development	1.4
Volume development	1.68
Av. annual rainfall (mm)	1203
Purpose	Irrigation

Sediment characteristics

Sediment was sandy-clay in nature comprising 71% sand, 12% silt and 17% clay. Soil reaction was slightly acidic (pH 6.2) in pre-monsoon and increased to near neutrality in the subsequent monsoons. Specific conductance was moderate (0.218 mS/cm). Organic carbon fluctuated to a low of 0.80% in pre-monsoon and to a high of 1.26% in monsoons. The catchment is covered with hillocks and forests with poor to moderate fertility status which got reflected in the content of organic carbon observed in this reservoir. C/N ratio was in the favourable range for productivity (16-20 mean: 18). Total-N content was in the range 0.052 to 0.063%. Available-N was moderately present in this reservoir to the tune of 28.31-34.65 mg/100g. Available-P content was low and ranged between 1.20 and 1.92 mg/100g. Free $CaCO_3$ exhibited narrow fluctuations amongst the seasons (mean: 2.7%).

Sediment characteristics of Sampna reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average
Sand (%)	72	69	71	72	71
Silt (%)	11	13	10	12	12
Clay (%)	17	18	19	16	17
pH	6.2	6.7	6.6	6.5	6.5
Sp.cond (mS/cm)	0.224	0.210	0.218	0.220	0.218
Org.C (%)	0.80	1.26	0.98	0.96	1.00
Total-N (%)	0.052	0.063	0.054	0.053	0.056
C/N	16	20	18	18	18
Avail-N (mg/100g)	32.72	34.65	30.12	28.31	31.45
Avail-P (mg/100g)	1.40	1.92	1.87	1.20	1.60
Free $CaCO_3$ (%)	2.8	2.5	2.6	2.8	2.7

Physico-chemical features of water

Water temperature fluctuated sinusoidally, low in winter (21°C) with an overall range of 21-29°C. Water remained transparent after cessation of monsoon rain and secchi depth increased from a low of 20 cm in monsoon to a high of 130 cm during post-monsoons. Thus, the average euphotic zone extended beyond 2.0 m year round suggesting medium productivity of this water body. The reservoir is not swept drastically by wind action as it passes through the gorge hillocks. So, chances of churning/mixing of nutrients from sediment to water phase is low, but it could overcome as the mean depth of this water body is low. Water reaction was moderately alkaline (pH 8.8-8.9). Availability of dissolved ions as reflected through the values of Sp. conductance were moderate. (126-244 µS/cm).

Physico-chemical features of water of Sampna reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Winter	Average
Temp. (°C)	28	29	23	21	25
Transp. (cm)	64	20	130	98	78
pH	8.8	8.9	8.9	8.8	8.8
Sp.cond (µS/cm)	244	126	172	190	183
TDS (mg/l)	159	82	112	124	119
DO (mg/l)	7.0	7.8	10.0	9.0	8.5
Carbonate (mg/l)	8	6	6	7	7
Bicarbonate(mg/l)	112	102	76	79	92
TA (mg/l)	120	108	82	86	99
TH (mg/l)	45	37	38	42	41
Ca^{+2} (mg/l)	9.62	8.02	8.02	8.02	8.42
Mg^{+2} (mg/l)	5.09	4.12	4.36	5.33	4.85
Cl^{-1} (mg/l)	17.04	14.20	14.20	15.62	15.26
NO_3-N (µg/l)	8	48	35	20	28
PO_4-P (µg/l)	10	26	22	8	17
Total-P (µg/l)	32	100	90	28	63
SiO_2-Si (mg/l)	1.6	1.9	1.8	1.7	1.8

Dissolved oxygen was in the favourable range (7.0-10.0 mg/l). Absence of Free CO_2 was noticed year round. The share of carbonate in total alkalinity was very meagre (6-8 mg/l) and bicarbonate alkalinity was in the range 76-112 mg/l. Total hardness was comparatively lower (37-45 mg/l) than the corresponding total alkalinity (82-120 mg/l) values and suggested that Sampna is a soft water reservoir. Obviously, calcium and magnesium ions were low ranging between 8.02 and 9.62 mg/l and 4.12 and 5.33 mg/l respectively. From the chloride content it could be concluded that the reservoir is a freshwater one with very little or no local pollution.

Nutrient status of water

Amongst available nutrients, dissolved inorganic-N basically NO_3-N was low in summer (8 mg/l) which was improved upon to some extent in monsoons and post-monsoons (35-48 µg/l) due to inflow. Soluble reactive phosphorus (PO_4-P) content was comparatively low (8-26 µg/l) than NO_3-N might be due to its quicker utilization by plankton as well its low loading into the reservoir through inflow from the catchment. Total-P content was also poor 28-100 µg/l in this reservoir. Silicate-Si was also of low concentration (1.6-1.9 mg/l) in this reservoir which might be due to its utilization by Bacillariophyceae.

Biotic communities

Plankton

The total plankton of Sampna varied from 366 u/l (0.70 ml/m^3) to 1746 u/l (1.83 ml/m^3). Two plankton peaks were observed in this reservoir, a distinct 'summer' (1746 u/l) and a low 'winter' (803 u/l). Phytoplankton (91.4%) was predominant with the dominance of Myxophyceae (47.0%) followed by Bacillariophyceae (32.4%) and Chlorophyceae (12.0%). Zooplankton (8.6%) was represented by Cladocerans (4.8%), Copepods (3.0%) and Rotifers (0.8%). The diversity of plankton was more in Sampna, 52 species were recorded representing phyto (20) and zoo (32) as shown below.

Plankton of Sampna reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Dinophyceae	Myxophyceae
Amphora	*Ankistrodesmus*	*Ceratium hirundinella*	*Anabaena*
Bacillaria paradoxa	*Hormidium*		*Anacystis cyanea*
Cymbella	*Palmella*		*Anacystis incerta*
Epithemia turgida	*Pediastrum simplex*		*Oscillatoria*
Gomphonema	*Phacus suecica*		
Melosira	*Volvox aureus*		
Navicula			
Nitzschia			
Synedra ulna			

Zooplankton

Cladocera	Copepoda	Protozoa	Rotifera
Acroperus harpae	*Cyclops*	*Difflugia urceolata*	*Anuraeopsis fissa*
Alonella	*Diaptomus*	*Heterophrys myriopoda*	*Asplanchna priodonta*
Bosmina longirostris	*Limnocalanus*	*Pompholyxophrys punicea*	*Brachionus angularis*
Bosminopsis dietersi	Nauplii	*Vampyrella lateritia*	*Elosa woralli*
Ceriodaphnia cornuta			*Filinia longiseta*
Chydorus ovalis			*Gastropus stylifer*
Diaphanosoma			*Hexarthra mira*
Ilyocryptus spinifer			*Keratella cochlearis*
			Keratella valga
			Lecane aspasia
			Mytilina mucronata
			Polyarthra vulgaris
			Proales decipiens
			Proales fallaciosa
			Synchaeta pectinata
			Trichocerca capucina
			Trichocerca cylindrica

Macro-benthos

Macro-benthos of Sampna fluctuated in a narrow range 956-1174 nos/m^2. Dipterans (41.9%) were important closely followed by Gastropods (34.0%), Bivalves (13.9%), Odonates (8.4%) and Hemipterans (1.8%). The forms are given below:

Gastropods	*Bellamya, Thiara*
Bivalves	*Corbicula, Parreysia*
Dipterans	*Chironomus, Chaoborus*
Odonates	*Anax*
Hemipterans	*Laccotrephes*

Periphyton

Periphyton of Sampna ranged from 78 u/cm^2 (0.02 ml/cm^2) to 1515 u/cm^2 (0.15 ml/cm^2) exhibiting two peaks, 'summer' (1515 u/cm^2) and 'winter' (1010 u/cm^2). Diatoms (74.3%) were most outstanding followed by Blue-green algae (19.2%), Green algae (6.2%) and Desmids (0.3%). The forms recorded from Sampna are given in the following table.

Periphyton of Sampna reservoir

Bacillariophyceae	Chlorophyceae	Desmidiaceae	Myxophyceae
Amphora	*Genicularia*	*Cosmarium*	*Amphithrix*
Cymbella	*Gonatozygon*		*Anabaena*
Navicula	*Hormidium*		*Phormidium*
Nitzschia	*Pediastrum simplex*		
Rhopalodia			
Surirella			
Synedra			
Tabellaria			

Macrophytes

During the course of present study, no macrophyte was seen in this reservoir.

Fish yield and catch composition

Sampna reservoir was under the control of Madhya Pradesh Fisheries Department till 1995 when its fish production ranged from 0.8 to 2.5 t during 1990-91 to 1994-95. The fishing was conducted on royalty system giving the reservoir either to the Co-operative Societies or the Fisherman Groups. The royalty was taken @ Rs. 10/kg for major carps, Rs. 7.50/ kg for local major and Rs. 5.00/kg for local minor. Later, the reservoir was handed over to the District Panchayat, Betul. The Panchayat gave this reservoir to a local Fisherman Group on lease for seven years. The lease amount was Rs. 27,380.00 for one year with an increase of 10% after two years.

During the period from 1991 to 1998, the fish production of Sampna ranged from 0.8 to 23.0 t. The local minor (71.7%) were dominant. Among the important carps, *C. catla* (21.8%) was important followed by *L. rohita* (2.3%), *T. tor* (1.3%), *C. mrigala* (1.2%), *C. carpio* (1.0%) and *L. calbasu* (0.5%)

The fish catch is being recorded under two categories only at present - "Big" and "Small". All the fishes weighing more than 2 kg are placed under "Big" category and those below 2 kg under "Small".

During the present investigations (1998-99), it was observed that Tilapia (*O. mossambicus*) developed good population in Sampna. The occurrence of Big-head (*H. Aristichthys nobilis*) was also observed in Sampna. It was also gathered from the Fisherman Group that the Big-head has also been stocked in Sampna. The seed (50,000) of Big-head (50 mm size) was stocked in August, 1997. The growth of *C. catla* was adversely affected with the introduction of Big-head in Sampna. In such a situation there is every possibility that this reservoir may get infested with Tilapia and Big-head in future.

It is a sad commentary that there is no organised and systematic fishing in Sampna reservoir presently. The Fisherman Group engaged in the commercial exploitation of Sampna has no proper fishing implements. Due to this reason also, the fishing effort is irregular and half-hearted.

Stocking

During 1990-91 to 1997-98, the reservoir was stocked with fingerlings (1.6- 4.1 lakh/y) with the species composition *C. catla* (34%), *L. rohita* (30%), *C. mrigala* (34%) and *C. idella* (2%). The retrieval of major carps in relation to stocking was negligible (0.1%). The breeding of major carps has never been observed in this reservoir. With a check on Tilapia and Big-head, the reservoir may be stocked @ 1500 fingerlings/ha/y in the ratio 5 catla : 3 rohu : 2 mrigal (100-125 mm).

Primary production

The GPP (mgC/m^3/h) in this reservoir also showed little variation with seasons, the maximum value obtained in pre-monsoon (110.4 mg) and slightly lower in post-monsoon (93.8 mg) with

the lowest in monsoon (72.6 mg) months. Even, being a small reservoir, the gross primary production was significantly poor in this water body. The C/A ratio (17%) was moderate indicating poor fertility status of the catchment. The NPP (mgC/m^3/h) ranged between 38.5 and 78.2, giving the reservoir an average assimilation efficiency of 62.7% - a productive character of this reservoir. P : R ratio showed a little variation with seasons (2.1 to 3.4) representing autotrophic mode of production in Sampna.

Productivity status

It is a small reservoir having good production criteria like moderate C/A ratio (17), moderate GPP (92.3 mgC/m^3/h) with supportive assimilation efficiency (62.7%). Sediment and water characteristics indicate the reservoir as a medium productive one. Considering catchment ecology and assuming a judicial conversion efficiency of 0.8% GP, the TPFY would be around 325 kg/ha/y. The present maximum fish yield from this water body is 90 kg/ha/y. Thus, there is an ample scope of augmenting the production at least two-folds which could better be realised through sustainable developmental options.

Plausible management guidelines

- Sampna requires a systematic and organised commercial exploitation to get the better results and production from this reservoir.
- The fisherman Group involved in the fishing of Sampna needs technical as well as financial assistance. The man-power is insufficient and ill-equipped for fishing in this reservoir.
- The data on fish catch statistics and fish seed stocking need to be maintained properly.
- The occurrence of Tilapia and Big-head in Sampna is a cause of concern. The stocking of Big-head should be stopped completely.
- The intensive fishing round the year and heavy stocking of major carps may bring down the population of Tilapia to provide a foundation for development of major carps in this reservoir.

SARNI RESERVOIR

Sarni reservoir (22°8′30″N & 77°11′E, 440 m asl) was constructed in 1967 across the river Tawa, the main tributary of Narmada, 38 km above Tawa Dam having a water spread 1012 ha. It is exclusively meant to meet the water requirements for Satpura thermal power plant (STPP), adjacent to the reservoir for cooling different operational systems. The first unit of this power station started production in 1967. The operation of such plants results in atmospheric pollution caused due to fly ash and thermal pollution due to discharge of warm water into the reservoir. Discharge of large quantities of waste from power plant also affects the ecology of the reservoir. Temperature is the limiting factor controlling the bio-productivity of the water body.

The Tawa river originates from Satpura range (Mahadeo hills) at an elevation of 762.5 m asl. The catchment (353.1 km^2) is characterised by average annual rainfall 1524 mm with maximum precipitation (67%) occurring in July and August. The catchment of Sarni is neither denuded nor that much fertile to supply substantial amount of allochthonous inputs into the reservoir particularly during monsoon inflow. The hot water released by STPP having 7 - 8°C above the ambient temperature is discharged into the river, 1.5 km above the confluence of the river and the reservoir through a 3.5 km long hot water canal. No fly ash was noticed neither in water nor in sediment of the reservoir. The fly ash of the STPP is being dumped into a separate dumping ground (Rakhar Bund) 5 km away from the power plant. This reservoir was studied during 1999-2000.

Salient morphometric and hydrographic features

Location (District)	Betul (M.P.)
Year of construction	1967
River	Tawa
Latitude	22° 8' 30" N
Longitude	78° 11' E
FRL (m)	436.76
Water spread at FRL (ha) A	1012
Water spread at DSL (ha)	800
Catchment area (km^2) C	353.1
C/A	35
Gross capacity (10^6 m^3)	92.52
Maximum depth (m)	28.97
Mean depth (m)	9.29
Shore line (km)	45
Shore development	4
Volume development	0.96
Maximum flood discharge (Cusecs)	135000
River System	Narmada
Average annual rainfall (mm)	1524

Sediment characteristics

The sediment is predominantly sandy-clay-loam with more clay noticed in the littoral sector. Soil reaction was slightly acidic to near neutral (pH 5.96-6.94; av. 6.3) and littoral soil was more acidic than profundal sector due to more clay content. Organic carbon was found more in

monsoon (1.39-1.51%) than post-monsoon (1.05-1.48%) and pre-monsoon (1.11-1.46%) months. Significantly, more organic carbon was registered in profundal zone due to aquatic vegetation dominated by the species of *Hydrilla, Vallisneria, Potamogeton, Nymphea* and *Eichhornia* which were abundant mostly in pre-monsoon months, scattered in patches with lump formation in the lentic profundal sector of Sarni. Total-N did not vary widely and ranged between 0.11 and 0.19%. C/N ratio, an estimator of degree of organic matter decomposition was in the range 6-13, a quite favourable range for productivity, enabling release of nutrients from the sediment to water phase. Available-N (43 mg/100 g) was moderate while available -P (2.2 mg/100 g) was quite low. Free $CaCO_3$ was in the range 0.88 to 1.58%. N/P ratio, was very moderate (10-19) in case of profundal zone and substantially higher (19-52) in littoral soil reflecting more available-N in the latter sector.

Sediment characteristics of Sarni reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average (Profundal)	Average (Littoral)
pH	6.08	6.94	6.45	6.49	6.12
Sp.cond (mS/cm)	0.27	0.26	0.24	0.26	0.30
Org.C (%)	1.46	1.51	1.48	1.48	1.18
Total-N (%)	0.11	0.15	0.12	0.13	0.18
C/N	13	10	12	12	7
Avail-N (mg/100g)	30.8	42.0	33.6	35.46	49.47
Avail-P (mg/100g)	2.04	4.37	1.80	2.74	1.66
Free $CaCO_3$ (%)	1.28	1.58	1.50	1.45	0.99

Physical features of water

Fluctuation in water depth was narrow during the sampling periods (1.0 m) as the reservoir water is supplied to STPP only and in turn the hot water is being recycled into the reservoir. Except on occasions of extreme summer the little fluctuation in water depth has a great bearing on productivity which is a very favourable feature of this reservoir.

Prevailing climatic conditions are very pronounced in this part of the country. The Central India exhibits air temperature with summer high in May (42.0-44.3°C) and winter low in December-January (8.7-10.5°C). During the sampling periods, the air temperature fluctuated between 24 and 27°C in this reservoir maintaining water temperature fairly high in the range 25 to 27°C. Water temperature is severely influenced by the hot water discharge of STPP and most phenomenal during May when reservoir water level is at its low. Water temperature recorded on 9th March 2000 was 35.5°C at hot water discharge point in the river Tawa, 28°C at 1 km above the outfall point in the river and 34°C at the confluence of reservoir and the river which is 1.5 km down to the discharge point. Though the water temperature from the confluence towards the lentic zone of the reservoir gets stabilised between July and March but the voluminous hot water being discharged into the reservoir leads to increase the ambient temperature which is reported to be more pronounced during April to June to the extent of 33.5 to 35°C even at 9 am.

Physico-chemical features of water in Sarni reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Temp. (°C)	26.8	27.0	25.0	26.3
Transp. (cm)	215	15	150	127
pH	7.66	6.75	7.36	7.26
Sp. cond. (µS/cm)	350	133	320	268
TDS (mg/l)	228	87	208	174
DO (mg/l)	7.0	6.9	7.0	7.0
Free CO_2 (mg/l)	0	3.0	2.0	-
Carbonate (mg/l)	40	0	0	-
Bicarbonate(mg/l)	54	62	74	63
TA (mg/l)	94	62	74	77
TH (mg/l)	53	52	52	52
Ca^{+2} (mg/l)	20.04	16.03	18.02	18.03
Mg^{+2} (mg/l)	0.70	2.90	1.69	1.76
Cl^{-1} (mg/l)	19.88	14.20	16.30	16.79
NO_3-N (µg/l)	10	272	200	161
PO_4-P (µg/l)	10	70	30	37
Total-P (µg/l)	38	256	110	135
SiO_2-Si (mg/l)	6.33	2.50	4.99	4.61

Secchi depth went beyond 2.0 m in pre-monsoon from 0.15 m in monsoon. The suspended clay micelles subsequently got settled with the cessation of inflow and the euphotic zone extended even more than 4.0 m during post-monsoon. The attributing factors of transparency are wind action, plankton concentration, suspended silt particles and organic matter deposition at the bottom. In this reservoir, light penetration was not hindered at all by algal bloom throughout the year. Lentic water was more transparent than intermediate and lotic but not significant indicating that very little or no fly ash was coming to the reservoir through hot water discharge from the plant.

Other physical processes like wind action matters greatly as the reservoir is swept by heavy wind in most part of the year excepting winter due to its flattened shape with minimum bays and coves. The wind-induced turbulence churns the water to facilitate nutrient mixing, pumping DO into the entire water column and distribution of heat rendering in equilibrium of temperature.

Chemical characteristics of water

DO was relatively moderate at the surface (6.9 to 7.0 mg/l). Seasonal variation in DO was insignificant due to strong wind action and absence of any *Microcystis* bloom all the year round. DO in riverine water was somewhat higher 7.5 to 8.0 mg/l than lacustrine area.

Free CO_2 was found in monsoon (3.0 mg/l) and post-monsoon (2.0 mg/l) in the surface water with complete absence in pre-monsoon months. Phytoplankton utilize carbonate and bicarbonate as their CO_2 source for photosynthesis during summer months. But free CO_2 remained present at the bottom mostly, indicating that the reservoir is productive. The absence

of CO_2 in summer months is mainly due to higher rate of utilization during photosynthesis and clear water coupled with prolonged sunshine.

Water reaction was nearly neutral (pH 7.26) varied to the extent of 6.75 (monsoon) to 7.66 (pre-monsoon). Specific conductivity was in the range 133 (monsoon) to 350 µS/cm (pre-monsoon) without any spatial variation. The wide temporal variation of conductivity in Sarni might be due to influx of hot water from the power plant resulting in dissolution of more number of ions. Soluble salts in any sheet of water are very important from the point of view of biological productivity. Specific conductivity above 200 µS/cm is found to be optimal for fish production. In this reservoir, it is in conducive range for productivity. Total dissolved salts ranged from 87 to 228 mg/l in this reservoir.

Total alkalinity varied widely to the tune of 62 (monsoon) to 94 mg/l (pre-monsoon) with low value in monsoon due to dilution effect, registering phenomenal presence of carbonate (40 mg/l) during pre-monsoon season only. The spatial variation in total alkalinity was not significant in this water body. This reservoir can be grouped under medium productive one as total alkalinity ranged from 40 to 90 mg/l.

It is a soft water reservoir with little fluctuation in spatio-temporal variations in total hardness (TH) in the range 52 - 53 mg/l. TH was less than its corresponding TA value, some of the carbonates and bicarbonates were associated with Na and K rather than Ca and Mg. For productive waters, a small amount of Ca and Mg are required and the necessary quantities are mostly present if TH is above 20 mg/l. In Sarni, Ca was moderate (16.03 - 20.04 mg/l) with low Mg content (0.70 - 2.90 mg/l). High Ca in this reservoir was also reflected in the bottom fauna of the lake dominated by molluscs. The dominant molluscan littoral fauna while dead, add considerably to the $CaCO_3$ in soil deposits. The higher Ca content in the early monsoon may be attributed to the decay of dead molluscan shells.

A higher amount of chloride in water is indicative of water pollution. In this study, chloride (mg/l) was noticed to the extent of 14.20 (monsoon) to 19.88 (pre-monsoon) with corresponding salinity (mg/l) 55.63 to 65.88 respectively representing a non- polluted reservoir.

Stratification in Sarni

The ambient water temperature is quite high and is on increasing trend with the progress of summer due to incoming hot water discharge by the STPP and has never fallen below 24 C at the bottom (12 m from the surface) even during post-monsoon months. So, stable thermal as well as chemical stratification are not expected from this reservoir. The maximum thermal stratification with low stability was noticed only during March with hypolimnion temperature at 12 m depth from the surface water has fallen by 1.8°C. With the progress of summer, homomictic thermal condition exists and remains stable for a longer period.

Accordingly, chemical stratification with poor clinograde distribution of oxygen registering a drop of 1.4 mg/l DO at the bottom from the surface was noticed in March. pH and total alkalinity have not dropped significantly at the hypolimnion. Due to absence of free CO_2 at the epilimnion only during pre-monsoon, the bicarbonate content was low at the epilimnion, subsequently increased at metalimnion with the resultant fall at hypolimnion in comparison to metalimnion. Presence of CO_2 all the year round at meta- and hypolimnion indicates that Sarni is a productive reservoir where substantial decomposition of bottom organic matter is taking place in this ambient water condition.

Nutrient status of water

Regarding essential nutrients, presence of nitrate-N was phenomenal in monsoon (272 µg/l) followed by post-monsoon (200 µg/l) but a quite low value registered in pre-monsoon (10 µg/l). Total inorganic-N was in good amount, maximum in monsoon (680 µg/l) and minimum in pre-monsoon (80 µg/l). Available-P was poor as compared to available-N and varied to the extent of 10 µg/l in pre-monsoon to 70 µg/l in monsoon (av. 37 µg/l). More nutrients were encountered in monsoon and post-monsoon due to loading of allochthonous inputs from the catchment with inflow. Most of the Indian reservoirs are deficient in phosphate as well as nitrate. Silicate - Si was quite low in monsoon (2.50 mg/l) and moderately present in post-monsoon (4.99 mg/l) and pre-monsoon (6.33 mg/l) to support a good crop of Bacillariophyceae in these seasons.

Biotic communities

Plankton

The total plankton varied from 42 u/l (0.14 ml/m^3) to 254 u/l (1.41 ml/m^3) showing a winter pulse only observed in December. Phytoplankton (69.0%) comprising Bacillariophyceae (53.0%) contributed by 9 species, Chlorophyceae (14.2%) by 8 species and Myxophyceae (1.8%) by 5 species was dominant. Zooplankton (31.0%) was represented by Cladocerans (16.5%) with 6 species, Copepods (13.6%) with 3 species and Rotifers (0.9%) with 9 species.

The planktonic forms recorded from Sarni during the study period are listed in following table. It merits mention that some of the groups/forms not available in quantitative estimation were observed in qualitative assessment.

Plankton of Sarni reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Myxophyceae
Cymbella	*Characium*	*Coelosphaerium*
Diatoma	*Gonatozygon*	*Lyngbya*
Nitzschia	*Hormidium*	*Oscillatoria*
Fragilaria	*Coccomyxa dispar*	*Spirulina*
Gyrosigma	*Euglena*	*Stichosiphon*
Synedra	*Pediastrum*	
Rhopalodia	*Phacus*	
Navicula	*Spirogyra*	
Tabellaria		

Zooplankton

Cladocera	Copepoda	Protozoa	Rotifera
Bosminopsis dietersi	*Cyclops*	*Plagiopyxis*	*Anuraeopsis fissa*
Bosmina	*Diaptomus*	*Pompholyxophrys*	*Brachionus angularis*
Ceriodaphnia cornuta	*Mesocyclops*		*Brachionus havanaensis*
Chydorus	Nauplii		*Filinia brachiata*
Diaphanosoma			*Filinia minuta*
Ophryoxus gracilis			*Gastropus*
			Keratella
			Lecane aspasia
			Ploesoma

Macro-benthos

Macro-benthic population ranged from 1044 to 2913 nos/m^2 (av. 1742 nos/m^2). Dipterans (37.4%) were important followed by Gastropods (29.7%), Oligochaetes (27.2%) and Bivalves (5.7%). Macro-benthos was more in littoral zone as compared to sub-littoral and profoundal zones of the reservoir. Zonal variation in macro-benthos was observed in Sarni. The prevalence of Oligochaetes was noticed in deeper regions. Observations were made in out fall zones of thermal discharge into the reservoir. High water temperature zones exhibited more molluscs whereas dipterans and oligochaetes were significant at low temperature areas. The available forms are given below :

Dipterans : *Chironomus, Chaoborus, Lumbricillus*
Gastropods :*Thiara, Bellamya*
Bivalves : *Parreysia, Lamellidens, Corbicula*
Oligochaetes : *Stylaria, Nais, Chaetogaster, Dero*

Periphyton

Periphyton fluctuated between 115 u/cm^2 (0.05 ml/cm^2) and 2640 u/cm^2 (0.20 ml/cm^2) with a very prominent winter pulse which was noticed in December. Diatoms (90.8%) represented by 13 species were predominant with poor occurrence of Blue-green (5.1%) with 4 species and Green algae (4.1%) with 6 species. The periphytic forms are shown below.

Periphyton of Sarni reservoir

Bacillariophyceae		Chlorophyceae	Myxophyceae
Asterionella	*Meridion*	*Characiopsis*	*Amphithrix*
Bacillaria	*Navicula*	*Characium*	*Oscillatoria*
Cymbella	*Nitzschia*	*Gonatozygon*	*Phormidium*
Diatoma	*Rhopalodia*	*Microspora*	*Stichosiphon*
Gomphonema	*Synedra*	*Rhizoclonium*	
Gyrosigma	*Tabellaria*	*Spirogyra*	
Mastogloia			

Zooplankton

Cladocera	Copepoda	Protozoa	Rotifera
Bosminopsis dietersi	*Cyclops*	*Plagiopyxis*	*Anuraeopsis fissa*
Bosmina	*Diaptomus*	*Pompholyxophrys*	*Brachionus angularis*
Ceriodaphnia cornuta	*Mesocyclops*		*Brachionus havanaensis*
Chydorus	Nauplii		*Filinia brachiata*
Diaphanosoma			*Filinia minuta*
Ophryoxus gracilis			*Gastropus*
			Keratella
			Lecane aspasia
			Ploesoma

Macro-benthos

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Periphyton of Sarni reservoir

Bacillariophyceae		Chlorophyceae	Myxophyceae
Asterionella	*Meridion*	*Characiopsis*	*Amphithrix*
Bacillaria	*Navicula*	*Characium*	*Oscillatoria*
Cymbella	*Nitzschia*	*Gonatozygon*	*Phormidium*
Diatoma	*Rhopalodia*	*Microspora*	*Stichosiphon*
Gomphonema	*Synedra*	*Rhizoclonium*	
Gyrosigma	*Tabellaria*	*Spirogyra*	
Mastogloia			

Macrophytes

The reservoir has dense population of macrophytes like *Nymphaea, Hydrilla, Vallisneria, Potamogeton, Eichhornia crassipes.* The occurrence of *Ipomoea* and *Typha* was also observed. The warm water results in permanent growth of macrophytes. The nutrients available in the ecosystem are consumed by macrophytes to affect the reservoir productivity reducing the production at primary and secondary trophic levels. Consequently, the plankton biomass is poor in Sarni.

Fish fauna

27 species belonging to 7 families and 18 genera were recorded from Sarni reservoir as presented below:

NOTOPTERIDAE	
	Notopterus notopterus (Pallas)
CYPRINIDAE	
	Catla catla (Ham-Buch)
	Cirrhinus mrigala (Ham-Buch)
	Cirrhinus reba (Ham-Buch)
	Labeo bata (Ham-Buch)
	Labeo calbasu (Ham-Buch)
	Labeo gonius (Ham-Buch)
	Labeo rohita (Ham-Buch)
	Osteobrama cotio cotio (Ham-Buch)
	Puntius sarana sarana (Ham-Buch)
	Puntius ticto (Ham-Buch)
	Tor tor (Ham-Buch)
	Chela laubuca (Ham-Buch)
	Salmostoma bacaila (Ham-Buch)
	Amblypharyngodon mola (Ham-Buch)
BAGRIDAE	
	Aorichthys aor (Ham-Buch)
	Aorichthys seenghala (Sykes)
	Mystus cavasius (Ham-Buch)
	Mystus gulio (Ham-Buch)
	Rita pavimentatus (Valenciennes)
SILURIDAE	
	Ompok pabda (Ham-Buch)
	Wallago attu (Schneider)
GOBIIDAE	
	Glossogobius giuris (Ham-Buch)
CHANNIDAE	
	Channa marulius (Ham-Buch)
	Channa striatus (Bloch)
	Channa orientalis (Bloch & Schneider)
MASTACEMBELIDAE	
	Mastacembelus armatus (Lacepede)

Quality composition of biotic communities of Sarni reservoir (1999-2000)

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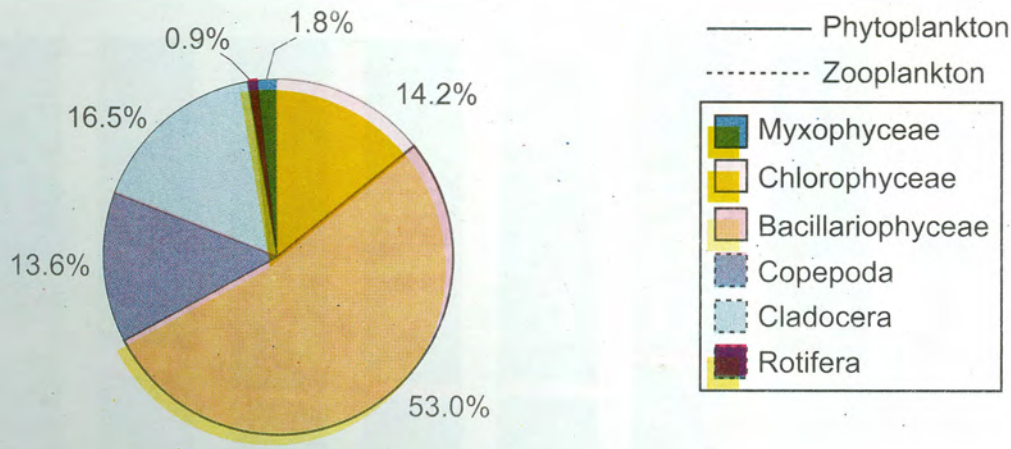

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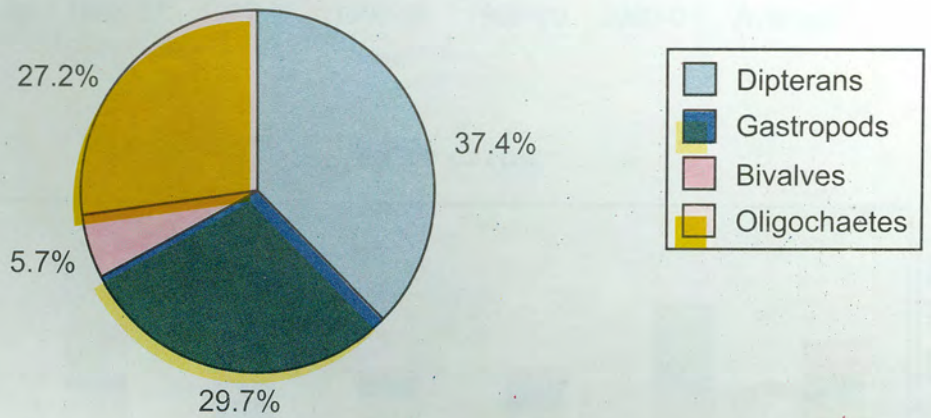

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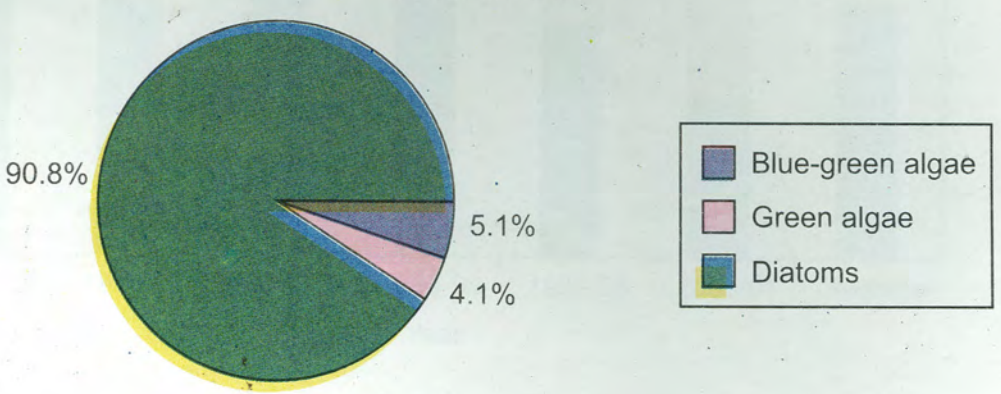
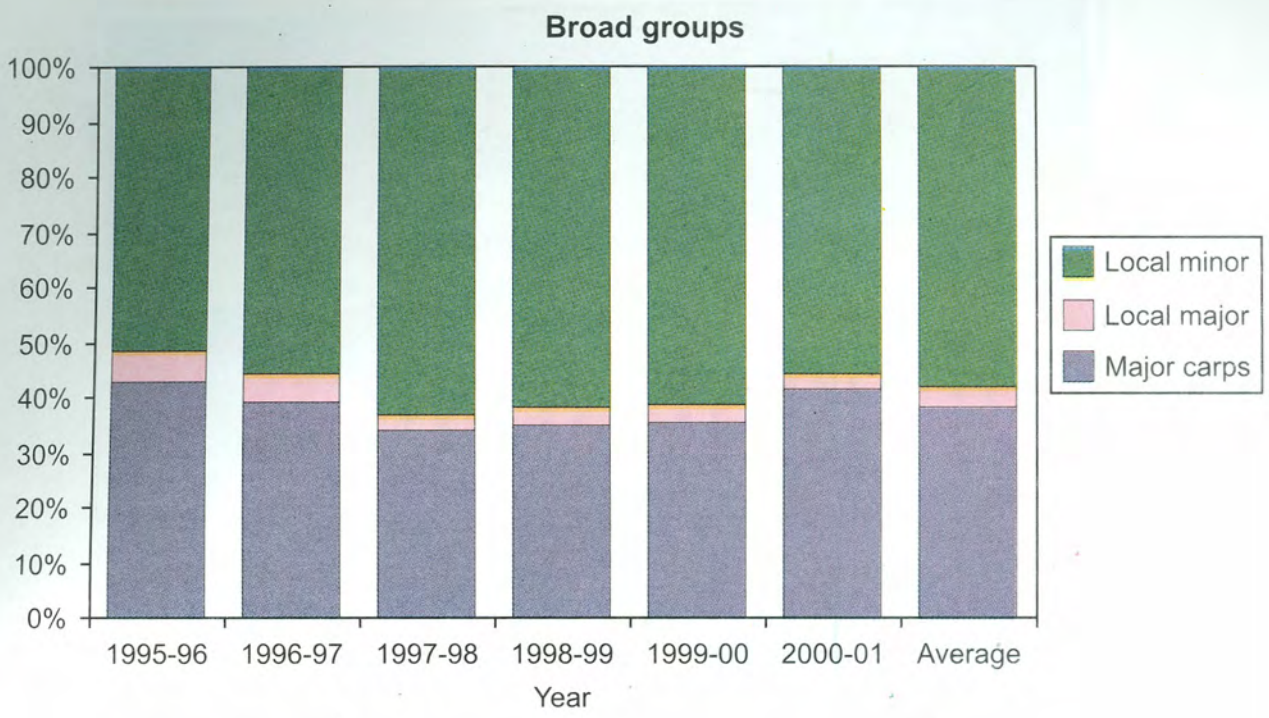
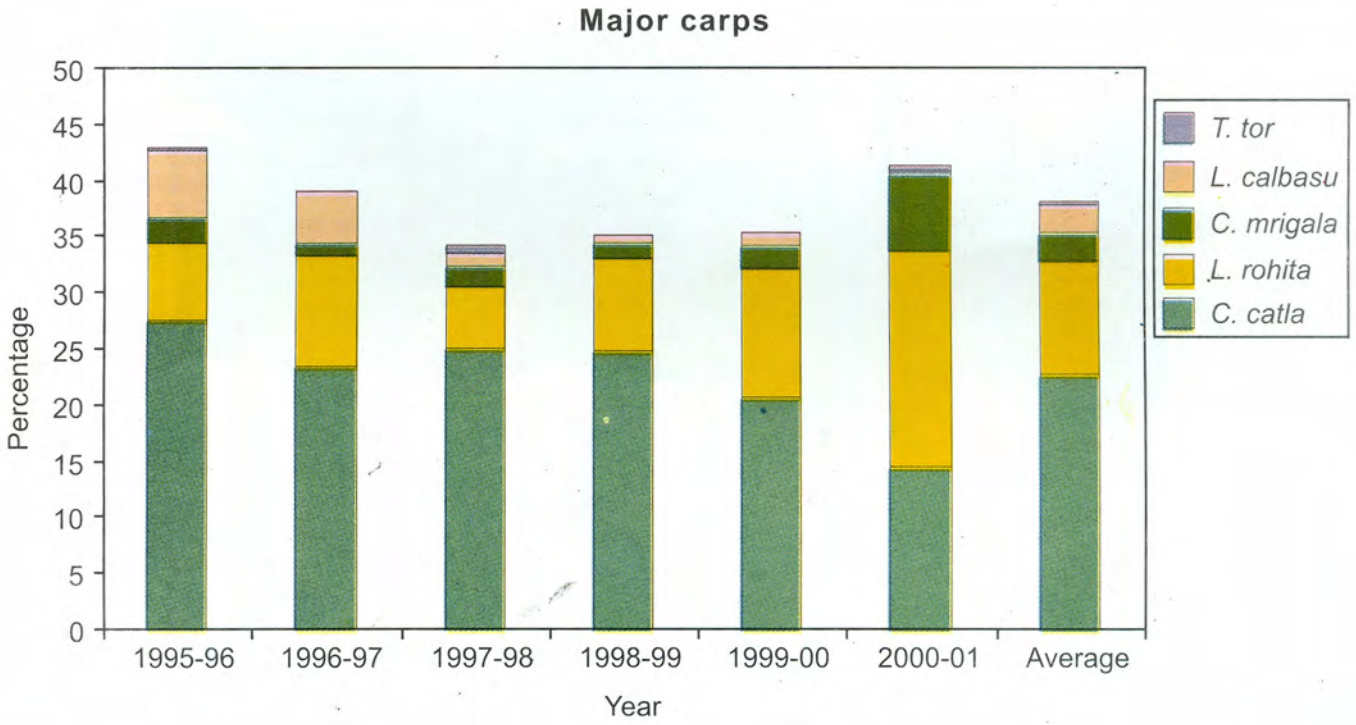


Fish catch composition (%) of Sarni reservoir (1995-96 to 2000-01)





Sarni reservoir with STPP

Hot water discharge from STPP

Sampling at Sarni

Fish catch of Sarni

Existing management

The fishing rights of the reservoir are with Madhya Pradesh State Fisheries for which the department pays an annual lease to State Electricity Board, owning the thermal power station. It was Rs. 23,293/- during 1999-2000. The fishing is conducted on royalty basis. The royalty rates were as follows during the period of study.

Major carps	Rs. 14/ kg
Local major (Major cat-fishes & Misc.)	Rs. 10/ kg
Local minor (medium carps, small-sized cat-fish and minnows)	Rs. 8/ kg

Four Co-operative Societies were engaged in the fishing of Sarni reservoir. The details are given below.

Sl. No	Name of the society	No. of members	No. of active members	Fisherman community
1.	Satpura Matsyodhyog Sahkari Samithi, Gopinathpur	55	30	Bengali
2.	Basanti Matsyodhyog Sahkari Samithi, Shaktigarh	33	25	Bengali
3.	Tawa Adivasi Matsyodhyog Sahkari Samithi, Lonia	29	6	Adivasi
4.	Matsyodhyog Sahkari Samiti, Sarni	50	12	Dheemar

The closed season is observed from 15th June to 15th August. The annual income to the Fisheries Department from this reservoir varied from Rs.1.44 to 3.99 lakh.

Fishery

The fish yield of Sarni reservoir varied from 7.3 t (8 kg/ha) in 1978-79 to 65.1 t (72 kg/ha) in1985-86. The fishery is more or less static in recent years (1995-96 to 2000-01) varying between 39.1 and 53.1 t (av. 46.3 t).

The indigenous fishes like Local minor (58.2%) represented by medium carps, small-sized cat-fishes and minnows form the main bulk of fish catch. The Local major (large-sized cat-fishes) accounted for 3.8% only. Among major carps (38.0%), *C. catla* (22.6%) was important. Major carp fishery is declining from 1985-86 whereas cat-fishes and minnows are showing an increasing trend in Sarni.

Fishing effort

The main fishing gears are gill nets (40-140 mm bar). More commonly used bars in the commercial fishing were 40, 60 and 70 mm. Dragnet is also operated during low reservoir levels. Besides, cast net and long lines are also used. The catch of long lines includes *Mystus, Ompok, Notopterus* and *Mastacembelus* species mainly.

On an average 30 boats, 30 fishermen with 300 kg of nets/day are employed in the commercial exploitation of Sarni reservoir. The catch per unit of effort (CPUE) was worked out at 6.4 kg (95-96 to 2000-01).

Breeding of major carps

Breeding of major carps is a regular feature in Sarni. The eggs are collected in large number by State Fisheries Department. But due to more silt in lotic zone and also on account of discharge of hot water from thermal power plant in this zone, hatching of eggs is greatly handicapped. The cases of early maturation and breeding of carps particularly *C. mrigala* and *L. rohita* in March-April were reported from Sarni but the survival was a set-back in natural condition.

Stocking

The reservoir is being stocked regularly with major carp fingerlings every year. The stocking rate was low in the initial phase (0.4-2.75 lakh) till 1984-85. The delay in initial stocking of major carps has probably resulted in the stronghold of indigenous fishes in Sarni. The stocking was increased to 3.0-8.95 lakh in subsequent years. During 1998-99, 3.60 lakh fingerlings (400 nos./ha) were stocked in size 80-100 mm with greater emphasis on *L. rohita* (60%) followed by *C. mrigala* (25%) and *C. catla* (15%). The increased stocking of major carps is not reflected in the fish catches. On an experimental basis, 10,000 fingerlings of Grass carp were also stocked in sarni for the first time.

Primary production

Gross primary production (GPP) was estimated on an average at 82 mgC/m^3/h, a low of 71 mgC during monsoon while it attained the maximum value of 95 mgC during pre-monsoon months. Net primary production (NPP) also showed the same trend as GPP, more during summer months (76 mgC/m^3/h) and observed a low value in monsoon (50 mgC) with an average of 61 mgC, resulting an assimilation efficiency of around 74% in this reservoir - a productive criteria for this water body. Community respiration was more or less same irrespective of seasons (19-21 mgC/m^3/h) reflecting dominance of phytoplankton over zooplankton. P:R ratio ranging between 3.6 and 5.0 also represented autotrophic dominance over heterotrophic organisms in this reservoir.

Productivity status

The morphometric and drainage characteristics indicate medium productivity of Sarni. The phytoplankton primary production was estimated at 82 mgC/m^3/hr. The low productivity could be due to poor biomass of phytoplankton as whatever nutrient being released from the sediment as well as made available through inflow from the catchment, is immediately utilised by the macrophytes. So, any estimate of potential fish yield (PFY) based on gross primary production (GP) reflects only a part of the potential production. However, assuming a judicial conversion efficiency of 0.6% GP, the TPFY of Sarni would be around 215 kg/ha/y. Presently, the maximum fish harvest from this reservoir was 72 kg/ha/y. So, there is a large gap between TPFY and actual yield, which could be corrected following sustainable management norms.

Plausible management guidelines

The targeted yield potential warrants certain variations from the existing management practices like :

- The present stocking rate may be maintained. The size of the stocking material of major carps needs to be raised to 100-150 mm for better survival.
- More emphasis is to be given on stocking of *L. rohita* followed by *C. mrigala* and *C. catla.*
- Macrophytes should be eradicated as well as a little portion may be recycled into the system through stocking of suitable herbivorous fish.
- Minnows population should be exploited properly through intensive fishing using shore seines and small-meshed gill nets during the low water levels of the reservoir (February - June).
- Ban should be imposed on fishing during breeding season.
- Provision of a Fish Farm is essential to overcome the problem of hatching of eggs of major carps.

KOLAR RESERVOIR

Kolar is a major irrigation cum water supply project constructed with the World Bank assistance. The dam is located in district Sehore near village Lawakheri and approachable from Bhopal by all weather 30 km long road. The designed irrigation from this project is 45087 ha and the water supply to Bhopal city is 34 MGD. The construction of main dam was started in 1982 and river closure of earth dam was completed in June 1988. The work of spillway and crest gate was completed in June 1991. A barrage on Kolar main river was constructed about 30 km downstream of Kolar dam. Main canals on right bank and left bank of barrage started irrigation from 1990.

The total area coming under submergence is 2503 ha. The affected villages are 4. Ninety families of these villages were rehabilitated by providing all the civic amenities. The compensation and 5 acre land was given to each family of the oustees. Ecological investigations in this reservoir were carried out during 2000-01.

Salient morphometric and hydrographic features

Latitude	22° 58′ N
Longitude	77° 21′ E
Basin	Narmada
River	Kolar-tributary of river Narmada
FRL (m)	462.2
Mean depth (m)	11.3
Maximum depth (m)	42
Water spread at FRL (ha) A	2380
Catchment area (km^2) C	508
Catchment to reservoir area (C/A)	21
Productive area (ha)	1928
Gross stroage at FRL ($10^6 m^3$)	270
Number and size of spillway gates	8 Nos. (15 x 8.5 m, radial)
Av. annual inflow (10^6 m^3)	174.19
Flushing rate	0.65
Maximum floods (Cumecs)	8605
Minimum dry weather flow (Cumecs)	60
Designed flood (Cumecs)	6450
Shore line (km)	29.5
Shore development	1.7
Volume development	0.81
Av. Annual rainfall (mm)	1230

Sediment characteristics

The basin was characterised by Sandy-loam soil with around 24% silt and 16% clay content - a very productive criteria for this reservoir. Organic carbon content was poor, more during monsoon and post-monsoon with an average of 0.28%. Total -N content was slightly more during monsoon months (0.02%) and accordingly, the C/N ratio was lying in the range (14.2 - 19.4) of productivity. Available-N was also poor (28.8-38.5 mg/100g) and available-P was a limiting factor for this reservoir. Soil reaction was near neutrality like most of other M.P.

reservoirs signifying a productive basin sediment. Free $CaCO_3$ was very meagre in the range 1.2-2.8% in this reservoir.

Sediment characteristics of Kolar reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Sand (%)	70.5	50.2	60.8	60.5
Silt (%)	18.7	28.6	24.2	23.8
Clay (%)	10.8	21.2	15.0	15.7
pH	7.0	7.6	7.4	7.3
Sp. cond (mS/cm)	0.26	0.20	0.28	0.21
Organic - C (%)	0.20	0.30	0.35	0.28
Total -N (%)	0.014	0.020	0.018	0.017
C/N	14.2	15.0	19.4	16.2
Avail-N (mg/100g)	28.8	30.5	38.5	3.6
Avail-P (mg/100g)	1.98	1.60	1.10	1.56
Free $CaCO_3$ (%)	2.8	1.2	1.6	1.9

Physico-chemical features of water

Water temperature varied sinusoidally, with a low of 18.2°C in post monsoon months with an average of 26°C. The average water temperature would increase further due to prolonged summer with short duration winter. Secchi depth was beyond 1.5m, a productive criteria for this reservoir with extended euphotic zone of more than 4 m facilitating penetration of sunlight to the deeper bottom layer of water. Prevalence of wind action was significant in this reservoir having flat bottom basin favouring greater churning of the water column.

Physico-chemical features of water in Kolar reseroir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Temp (°C)	29.8	30.0	18.2	26.0
Transp (cm)	165	160	135	153
pH	7.90	7.67	7.54	7.70
Sp. cond (µS/cm)	380	310	320	337
TDS (mg/l)	247	201	208	210
DO (mg/l)	7.3	7.7	8.6	7.9
Carbonate (mg/l)	36	26	28	30
Bicarbonate (mg/l)	144	134	136	138
TA (mg/l)	180	160	164	168
TH (mg/l)	128	120	126	125
Ca^{+2} (mg/l)	28.08	32.06	32.06	30.73
Mg^{+2} (mg/l)	14.04	9.68	11.14	11.62
Cl^{-} (mg/l)	22.24	19.88	19.88	20.66
NO_3-N (µg/l)	20	30	38	30
PO_4-P (µg/l)	4	10	12	9
SiO_2-Si (mg/l)	2.50	3.78	3.10	3.13

Water reaction was alkaline to moderately alkaline (av. water pH 7.70) with little seasonal fluctuations. Specific conductance was in the range 310-380 µS/cm, like most of other central

Indian reservoirs with total dissolved salts being 220 mg/l on an average representing moderate rate of mineralization in this reservoir.

DO (mg/l) was slightly more in post-monsoon (8.6) due to low temperature of water, otherwise it was in the productive range 7-8 mg/l. Free CO_2 remained absent in the surface water throughout the year and only available to the extent of 3-4 mg/l in the bottom water layer below 15 m from the surface mostly in pre-monsoon periods. Though, total alkalinity (av. 168 mg/l) being dominated by bicarbonates (av. 138 mg/l), presence of carbonates was to the tune of 26-36 mg/l which is helpful in maintaining the strong buffering capacity of water in this reservoir, but carbonates mostly remained absent at the bottom in most occasions. Thus, the range of TA (160-180 mg/l) was conducive for good productivity of this reservoir.

Kolar is a moderately hard water reservoir as being reflected through its water hardness which was 125 mg/l with narrow seasonal fluctuations (range 120-128 mg/l). Calcium and magnesium were present moderately in this reservoir. The water body was free from local pollution as reflected by chloride content of water (20.66 mg/l) with little seasonality.

Stratification

Due to flat basin and strong wind action homogeneity in distribution of water temperature. DO, pH, TA, TH along the water column was observed mostly, barring March - April when a stable thermal stratification with the distinct meta- and hypolimnion and a resultant fall in bottom (25 m) temperature to the tune of 5-7°C was noticed. Though, bottom was not anoxic, but strong clinograde distribution of oxygen was evidenced even for a short period (2-3 months in early pre-monsoon) reflecting moderate to high tropholytic activities at the bottom. A maximum of 5-6 mg/l fall in DO concentration at hypolimnion (25 m from surface) was encountered in this reservoir. So, a stable chemical stratification with the resultant heterogeneity in water pH, TA, carbonates, bicarbonates and sp. conductance from surface to bottom though for a short period clearly indicated that the reservoir is very productive.

Nutrient status of water

Amongst nutrients in the sub-surface waters, nitrate -N (µg/l) was poor in the range 20-38, even the inflow from the catchment did not bring substantial allochthonous inputs, though C/A (21) was very moderate probably due to poor fertility in the catchment. Same was true in case of available phosphate (4-12 µg/l). Silicate-Si which supports diatomic growth, was on an average 3.13 mg/l without much seasonal variation. From the nutritional point of view the reservoir productivity was below moderate level probably due to nutritional sink at the bottom as the very high water level remained stagnated year round. Nutrient load at the bottom was more as compared to sub-surface column water as reflected during post-monsoon and summer months when nitrates occurred between 100 and 45 respectively. Available-phosphate was also more at the bottom, to the extent of 60 µg/l in post-monsoon and 30 µg/l in pre-monsoon periods.

Biotic communities

Plankton

Plankton varied from 141 u/l (0.21 ml/m^3) to 450 u/l (1.0 ml/m^3). Plankton showed two peaks, the 'summer' was observed in March and the 'winter' in December. Among phytoplankton

(41.7%), Bacillariophyceae (22.4%) with 7 species was important followed by Chlorophyceae (15.7%) with 6 species and Myxophyceae (3.6%) with 2 species. Zooplankton (58.3%) represented by Copepods (42.7%) with 2 species, Cladocerans (14.1%) with 5 species and Rotifers (1.5%) with 7 species had an edge over phytoplankton. Some of the groups like Desmidiaceae, Dinophyceae (Phyto), Anostraca and Protozoa (Zoo) each represented by a single species were observed in qualitative assessment only. The recorded forms of plankton are presented in tabulated form.

Plankton of Kolar reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Desmidiaceae	Dinophyceae	Myxophyceae
Cymbella	*Characium*	*Staurastrum leptocladium*	*Ceratium hirundinella*	*Anacystis*
Diatoma	*Gonatozygon*			*Coelosphaerium*
Gyrosigma	*Hormidium*			
Navicula	*Lobocystis dichotoma*			
Nitzschia	*Pediastrum duplex*			
Surirella	*Pediastrum simplex*			
Synedra ulna				

Zooplankton

Anostraca	Cladocera	Copepoda	Protozoa	Rotifera
Eubranchipus	*Bosminopsis*	*Cyclops*	*Difflugia*	*Asplanchna*
	Ceriodaphnia cornuta	*Diaptomus*		*Brachionus angularis*
	Chydorus ovalis	Nauplii		*Brachionus bidentata*
	Diaphanosoma			*Gastropus*
	Sida			*Hexarthra mira*
				Keratella heimalis
				Keratella cochlearis

Macro-benthos

Macro-benthic density of Kolar ranged from 259 to 2000 nos/m^2 (av. 1667 nos/m^2). The concentration was more in littoral zone which subsequently decreased in deeper zones. Dipterans (53.0%) were most important followed by Gastropods (24.4%), Oligochaetes (12.2%) and Bivalves (10.4%). While Molluscs formed the bulk of benthic biomass, Dipterans were more in number. *Chironomus, Chaoborus, Thiara, Bellamya, Parreysia, Corbicula, Lamellidens* were the important macro-benthic forms.

Periphyton

The average density of periphyton was estimated at 670 u/cm^2 (0.10 ml/cm^2) ranging from 19 u/cm^2 (0.01 ml/cm^2) to 1605 u/cm^2 (0.15 ml/cm^2). While the 'winter' pulse was observed in December (1605 u/cm^2), the 'summer' in March (675 u/cm^2). Diatoms (74.1%) with greater diversity having 14 species were most significant. Green algae (24.6%) with 4 species and Desmids (1.3%) with a single species only were the other periphytic groups. The available forms are shown below:

Periphyton of Kolar reservoir

Bacillariophyceae	Chlorophyceae	Desmidiaceae
Amphora	*Gonatozygon*	*Staurastrum*
Cocconeis	*Hormidium*	
Cymbella	*Pediastrum*	
Diatoma	*Spirogyra*	
Gomphonema		
Gyrosigma		
Mastogloia		
Navicula		
Nitzschia		
Pinnularia		
Rhopalodia		
Surirella		
Synedra		
Tabellaria		

Macrophytes

The occurrence of *Hydrilla, Vallisneria* and *Potamogeton* was observed in this reservoir with the greater proliferation during pre-monsoon months.

Fish catch and composition

The annual fish yield of Kolar varied from 0.8 t (0.4 kg/ha) in 1989-90 to 67.14 t (34.8 kg/ha) in 1998-99 showing an increasing trend. Major carps (65-84 %) with the dominance of *C. catla* (21-69 %) were most important with subdued contribution of *C. mrigala* (6-28 %), *L. rohita* (7-12 %) and *T. tor* (1-3 %). Local major accounted for 11-12 % and Local minor 4-6 %. Minnows were exploited in 1997-98 with a share of 20 % only.

Development of Mahseer fishery

It is an important reservoir to replenish the mahseer fishery. In Kolar Mahseer (*Tor tor*) formed a significant fishery (20.2-49.4%) from 1989 to 1991 which subsequently declined to 3.7-9.2% during 1992-94, going further down to 1.0-3.0% in 1995-2000. After the formation of dam, the breeding migration of mahseer was checked. The brood fish failed to reach the breeding grounds which adversely affected its breeding success and recruitment. Since mahseer was never stocked, the sizable stocks of this prized fish could not be built up in Kolar reservoir. The favourable geo-morphological conditions of the reservoir coupled with availability of macrophytes, molluscs and insects are conducive for culture and propagation of mahseer in Kolar. The growth of mahseer in Kolar was good, mahseer weighing 5 kg was also recorded from the commercial catches. The studies revealed that mahseer though at a low ebb in Kolar at present, showed suitability to the ecosystem and needs proper stocking support.

Fishing effort

Simple gill nets (50-140 mm bar) are used in the commercial fishing of the reservoir. In the commercial fishing of Kolar reservoir, 20 fishing units/day were employed. One fishing unit

Quality composition of biotic communities of Kolar reservoir (2000-2001)

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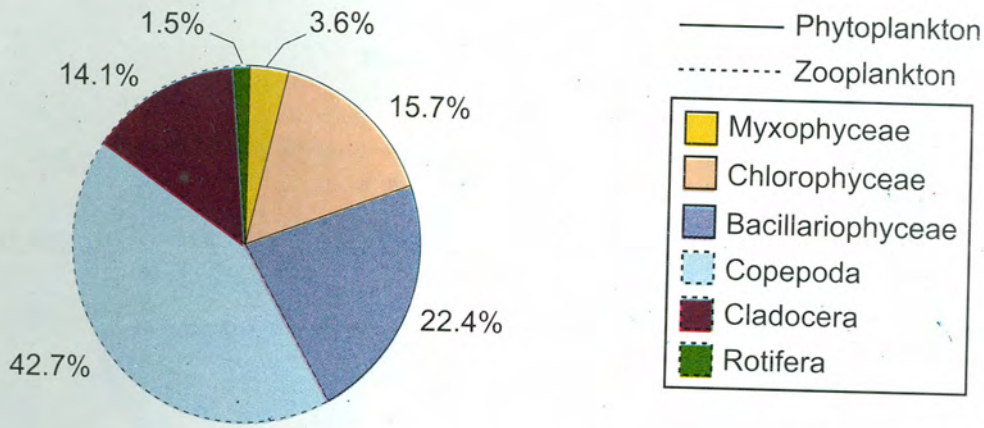

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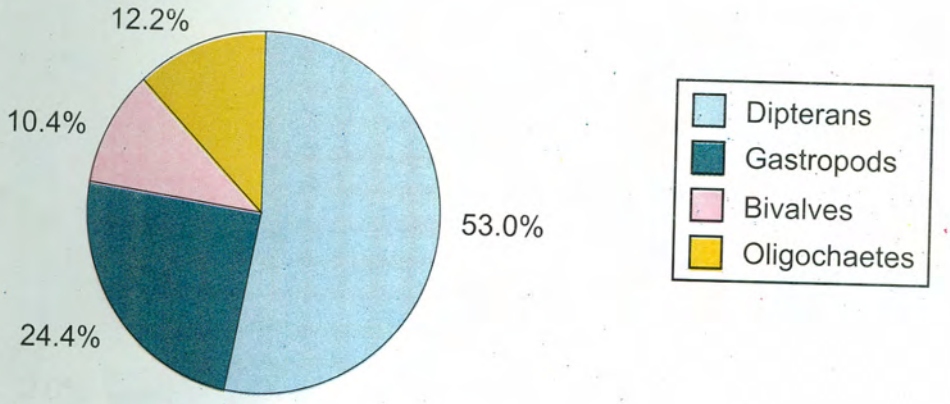

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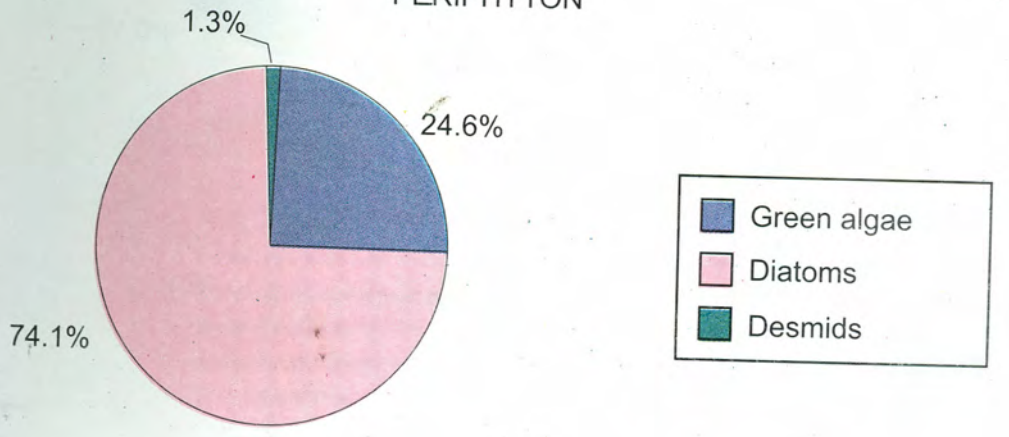
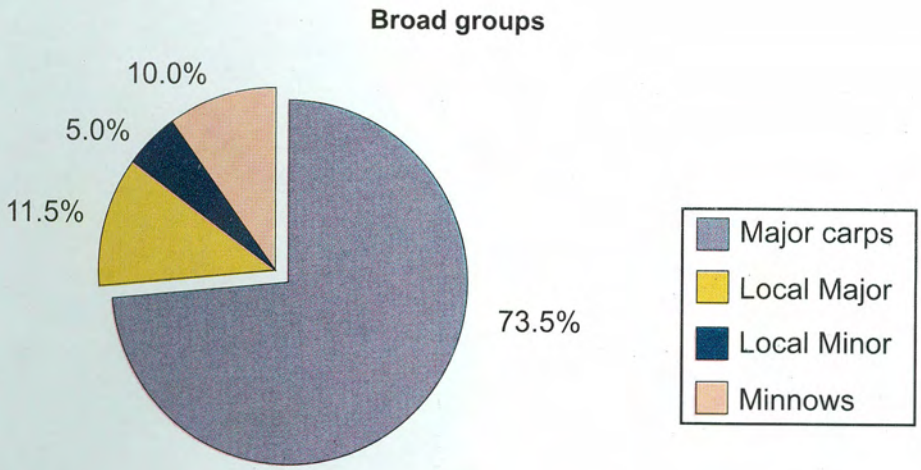
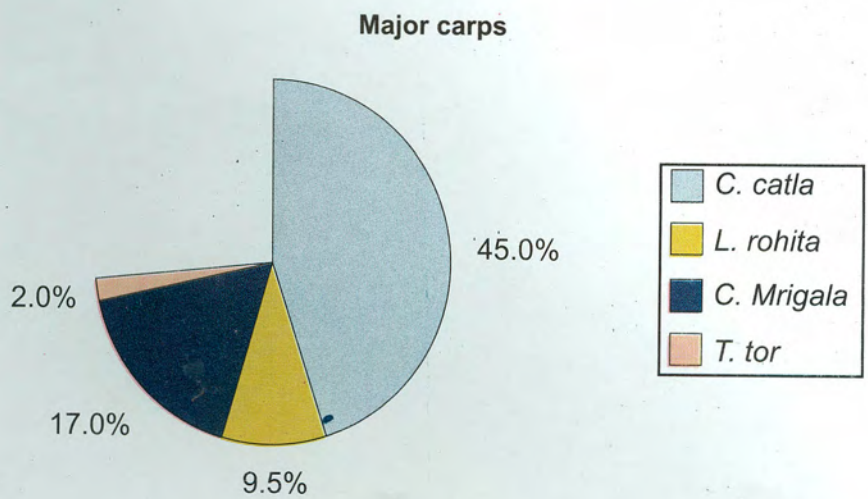


Fish catch composition (%) of Kolar reservoir (2000-01)





Kolar reservoir – Fishing party with catch

comprises one boat, two fishermen and 25 kg of nets. The catch per unit of effort (CPUE) varied from 10.0 to 12.3 kg during 1995-2000.

Stocking

The reservoir is being stocked regularly with fingerlings (3-4 lakh/y) @ 158-218 nos./ha with greater emphasis on *C. catla* (49%) followed by *L. rohita* (33%) and *C. mrigala* (18%). With the inclusion of mahseer in the stocking programme, the reservoir needs to be stocked @ 400 fingerlings/ha/y in the ratio 4 catla : 2 rohu : 2 mrigal : 2 mahseer (100 mm size).

Primary production

The GPP ($mgC/m^3/h$) was predominantly more in pre-monsoon (93.8) as compared to monsoon (72.7) months with an average of 81.3 mgC. Though the NPP ($mgC/m^3/h$) was more in summer months (62.8 mgC), the higher assimilation efficiency was attained in winter months (75%) with an average at 69%. The assimilation efficiency signified that the reservoir was moderately productive. P:R ratio did not vary widely (2.8 to 4.0) exhibiting autotrophic mode of production of this reservoir.

Productivity status

Kolar is a medium reservoir having a moderate C/A value (21), signifying medium productive nature well supported by its soil and water chemistry also. Based on primary productivity studies and assuming a judicial conversion efficiency of 0.4% GP, the TPFY of Kolar was estimated at 145 kg/ha/y. In view of present maximum harvest around 35 kg/ha/y, the reservoir offers ample scope to enhance the fish production further at least to the extent of 50% of TPFY through certain changes in present management practices.

Plausible management guidelines

- Catla fishery is declining in Kolar and needs the stocking support.
- Reservoir exhibited suitability to mahseer which should also be included in the stocking programme of Kolar. Initially, the share of mahseer could be 20% in the total stocking which on favourable results may further be enhanced. All available species of mahseer procuring the seed from Tata Electric Companies, Lonavala may be stocked in Kolar.
- A rational system of exploitation should be followed so as to reflect the diversity of all economically important species in the fish catch.
- Mesh size regulation banning the usage of gill nets below 50 mm bar, catching Catla below 2 kg and other major carps below 1 kg should be strictly enforced. The major carps should be allowed to grow and breed once in the reservoir to build up their stocks. The observance of closed season does help in this regard. Poaching - a common menace in all the reservoirs need to be dealt with constant and vigilant patrolling of the reservoir.

KERWA RESERVOIR

Kerwa - an irrigation project, harnesses the water of Kerwa river - a tributary to Kaliasote river which joins river Betwa. The reservoir was formed in 1975 by construction of dam in Tehsil Huzur, district Bhopal. It is 12 km from Bhopal city and is connected by a asphalted road from Bhopal city.

The Kerwa river at dam site passes through a narrow deep gorge for a distance of nearly 2.5 km. The dam site is at the beginning of this gorge. A pick-up weir approximately 1.5 km downstream of the dam site was constructed as direct canal system was not possible from Head Works due to very high and steep flanks on both sides in the gorge portion of the river. This reservoir has been studied during 2000-01.

Salient morphometric and hydrographic features

Latitude	22° 58' N
Longitude	77° 21' E
Basin	Betwa
River	Kerwa - tributary of river Kaliasote
FRL (m)	509.93
LSL (m)	500.79
River bed level (m)	490.42
Maximum depth (m)	20.7
Mean depth (m)	5.2
Water spread at FRL (ha) A	482
Catchment area (km^2) C	64.5
Catchment to reservoir area (C/A)	13
Productive area (ha)	347
Gross storage (10^6 m^3)	25
Dead storage (10^6 m^3)	2.4
Live storage (10^6 m^3)	22.6
Type of dam	Earthen, Homogeneous
Maximum inflow (10^6 m^3)	68.53
Minimum inflow (10^6 m^3)	6.85
Av. inflow (10^6 m^3)	31.89
Maximum floods (Cumecs)	594.5
Moderated floods (Cumecs)	453
Volume development	0.75
Av. annual rainfall (mm)	1166

Sediment characteristics

The basin soil was sandy-loam comprising 72.1% sand, 15.9% silt and 12.0% clay with more silt (18.1%) being loaded during monsoon. Soil reaction was moderately alkaline (soil pH 7.6) with little seasonal variations. Organic carbon content was in the range 0.38-0.60%, more in post-monsoon periods. Total -N (%) was significantly more as compared to other reservoirs under this study probably due to its smaller size with moderate C/A ratio (13) getting reflected into productive C/N ratio which ranged between 12 and 18, the average being 15. Available-N

was moderate to low with poor available -P content (1.53 mg/100g). Free $CaCO_3$ concentration was also very meagre in this reservoir.

Sediment characteristics of Kerwa reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Sand (%)	80.0	67.2	69.0	72.1
Silt (%)	13.0	18.1	16.6	15.9
Clay (%)	7.0	14.7	14.4	12.0
pH	7.5	7.7	7.6	7.6
Sp. cond. (mS/cm)	0.17	0.11	0.15	0.14
Organic- C(%)	0.38	0.45	0.60	0.48
Total-N (%)	0.032	0.025	0.043	0.033
C/N	12	18	14	15
Avail-N (mg/100 g)	40.42	32.20	38.65	37.09
Avail-P (mg/100 g)	0.80	2.50	1.28	1.53
Free $CaCO_3$ (%)	3.0	2.2	2.6	2.6

Physico-chemical features of water

Water temperature fluctuated to a low of 16.4°C in post-monsoon to a high of 33°C in pre-monsoon months keeping parity with the prevailing air temperature year round. Secchi depth was very low (av. 0.74 m) with extended euphotic zone only noticed beyond 2.5 m in summer months. Light penetration to the sub-surface waters was hindered due to suspended clay-micelles from June-November, limiting photosynthetic primary production during this period.

Water reaction was moderately alkaline (pH 8.1). Specific conductance showed a low value in monsoon (186 µS/cm) due to dilution effect, the average being 239 µS/cm. DO was in productive range year round. Free CO_2 remained absent in surface waters with its presence primarily in pre-monsoon months at the bottom (10 m) to the extent of 1-3 mg/l. Total alkalinity showed little seasonality with predominant presence of bicarbonate and the marked dilution effect in monsoon. Water of Kerwa was moderately hard in association with low to medium concentration of Ca^{+2} and Mg^{+2} cations. The reservoir did not show any sign of pollution as reflected by the concentration of chloride ions to the extent of 21.3 mg/l.

Physico-chemical features of water in Kerwa reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Temp (°C)	33.0	30.0	16.4	26.5
Transp. (cm)	100	52	70	74
pH	8.5	7.7	8.0	8.1
Sp. cond. (µS/cm)	340	186	192	239
TDS (mg/l)	221	121	125	156
DO (mg/l)	7.3	7.6	8.5	7.8
Carbonate (mg/l)	16	8	12	12
Bicarbonate (mg/l)	112	88	96	98
TA (mg/l)	128	96	108	110
TH (mg/l)	120	90	95	102
Ca^{+2} (mg/l)	29.0	21.0	22.0	24.0

Mg^{+2} (mg/l)	11.54	9.11	9.72	10.12
Cl^{-} (mg/l)	22.72	19.88	21.30	21.30
NO_3-N (µg/l)	15	30	35	27
PO_4-P (µg/l)	10	40	36	29
SiO_2-Si (mg/l)	2.6	3.0	3.6	3.1

Nutrient status of water

No significant presence of nutrients like available -N and phosphorus was observed at the bottom water column as compared to surface waters. The concentration of available -N and available -P in the upper water column fluctuated between 15 & 35 and 10 & 40 µg/l respectively. The low availability of nutrients at the bottom could be due to its shallow and convex nature of basin towards water coupled with strong wind action that swifted the reservoir in most occasions year round (barring winter months) resulting in complete churning of reservoir. Silicate-Si was present to the tune of 2.6-3.6 mg/l, supportive of moderate crop of Bacillariophyceae.

Biotic communities

Plankton

Plankton of Kerwa reservoir varied from 113 u/l (0.35 ml/m^3) to 521 u/l (0.70 ml/m^3) with the dominance of phyto- (60%) over zooplankton (40%). Unlike the observations of other reservoirs, a 'monsoon' pulse was noticed in August in Kerwa. The 'summer' pulse was observed in March. Bacillariophyceae (30.7%) with 2 species and Chlorophyceae (26.3%) with 4 species contributed mainly among phytoplankton. The occurrence of Myxophyceae (3.0%) with a single form was subdued. Zooplankton was represented by Copepods (26.6%) with 2 forms, Cladocerans (12.7%) with 3 forms and Rotifers (0.7%) with 2 forms. The different forms encountered from this reservoir are mentioned below.

Plankton of Kerwa reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Myxophyceae
Navicula	*Gonatozygon*	*Anacystis*
Synedra	*Hormidium*	
	Pediastrum duplex	
	Pediastrum simplex	

Zooplankton

Cladocera	Copepoda	Rotifera
Alona	*Cyclops*	*Brachionus*
Ceriodaphnia cornuta	*Diaptomus*	*Keratella heimalis*
Chydorus ovalis	Nauplii	

Quality composition of biotic communities of Kerwa reservoir (2000-2001)

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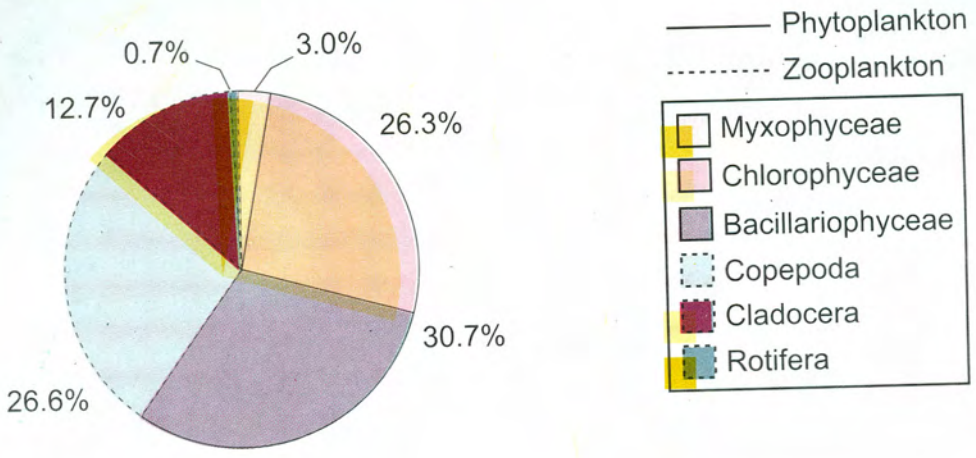
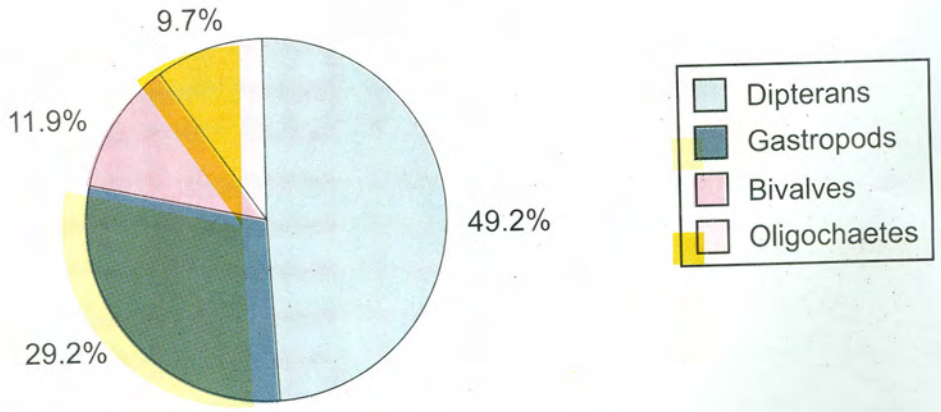


MACRO-BENTHOS



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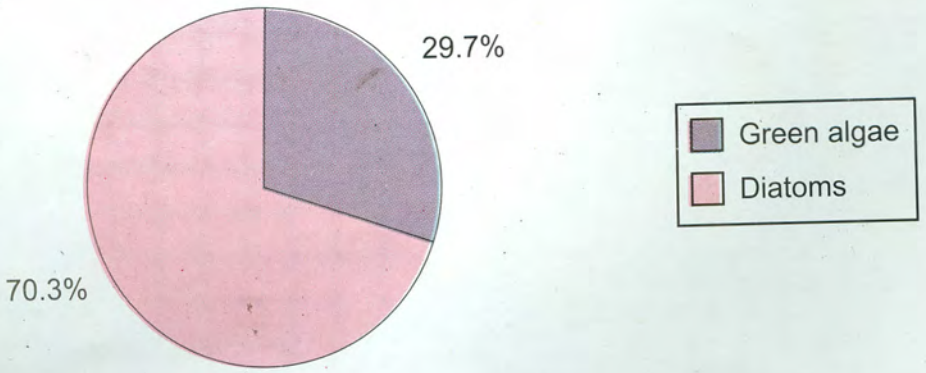
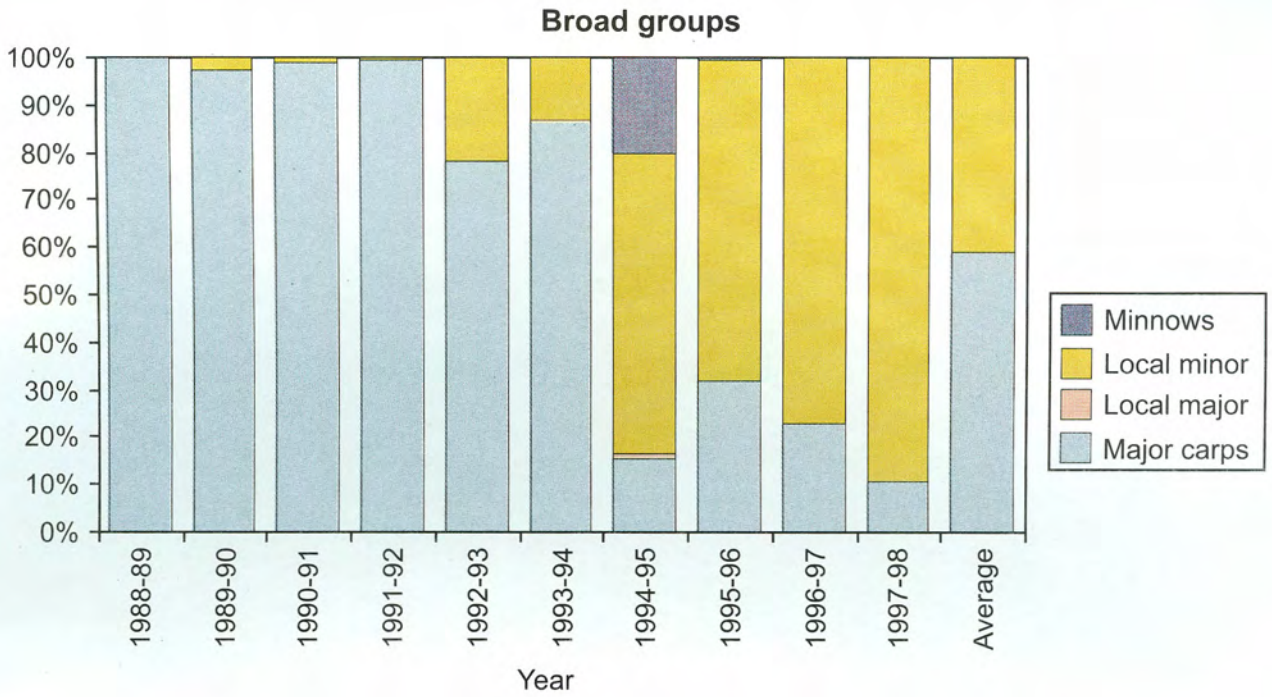
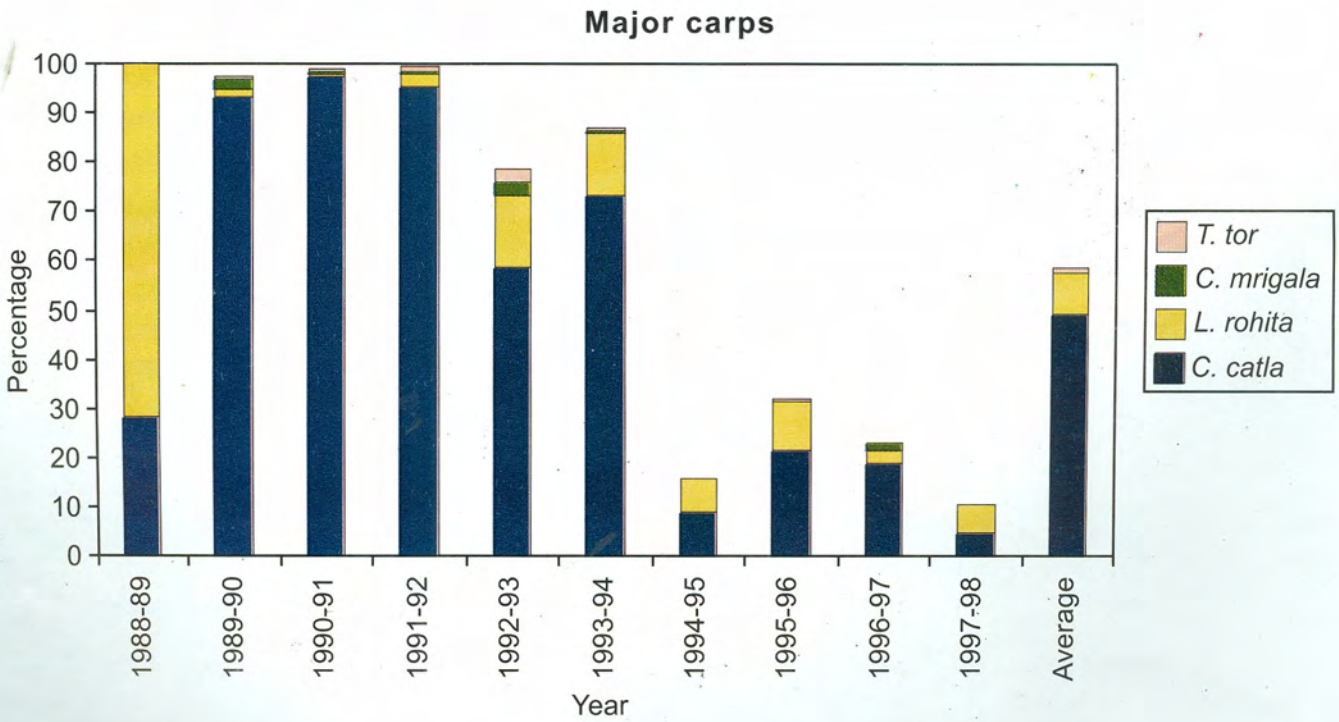


Fish catch composition (%) of Kerwa reservoir (1988-89 to 1997-98)





A view of Kerwa reservoir

Rocky bottom at lotic sector of kerwa

Macro-benthos

Macro-benthic population of Kerwa ranged from 435 to 2652 nos/m^2 (av. 1340 nos/m^2). The littoral zone exhibited greater concentration of macro-benthos than sub-littoral and profundal zones. Dipterans (49.2%) with *Chironomus, Chaoborus*; Gastropods (29.2%) with *Bellamya, Thiara*; Bivalves (11.9%) with *Parreysia, Corbicula* and Oligochaetes (9.7%) formed the total bulk of this biotic community.

Periphyton

The density of periphytic deposits in Kerwa ranged from 85 u/cm^2 (0.02 ml/cm^2) to 510 u/cm^2 (0.10 ml/cm^2) with the prevalence of Diatoms (70.3 %) with 7 periphytic forms. Green algae represented by 4 species accounted for 29.7%. Periphyton also exhibited a 'monsoon' pulse in August and 'summer' peak in March. The forms of periphyton are reported below:

Periphyton of Kerwa reservoir

Bacillariophyceae	Chlorophyceae
Amphora	*Gonatozygon*
Cymbella	*Hormidium*
Diatoma	*Pediastrum*
Gyrosigma	*Spirogyra*
Navicula	
Nitzschia	
Synedra	

Macrophytes

Hydrilla and *Vallisneria* with greater occurrence during summer months were observed in this reservoir.

Fish catch and catch composition

The annual fish yield of Kerwa varied from 0.5 to 25.0 t during 1988-99. The reservoir has given a maximum production of 72 kg/ha in 1998-99. Major carps (93.5%) with the dominance of *C. catla* (74.4%) were most significant till 1993-94. Its fishery declined (20%) thereafter with remarkable increase in local minor (74.5%). This group was represented by medium carps, small-sized cat-fish and minnows. The contribution of mahseer was poor earlier (0.4-2.4%), which increased to 5-10% at present.

Fishing effort

A fishing unit employed in the commercial fishing of this reservoir was represented by one boat with two fishermen and 25 kg of nets. The catch per unit of effort (CPUE) of Kerwa varied from 11 to 14 kg.

Development of mahseer

The Govt. of Madhya Pradesh has reserved Kerwa reservoir for the development of sport fishery of mahseer. It is also proposed to develop an angling centre so that mahseer could be linked up with tourism. The State has noticed a number of sanctuaries where fishing is punishable under Indian Fishery Act, 1898. At present Kerwa is also under this act. The fishing has been completely stopped and the reservoir is being stocked with mahseer seed only. Semi-fingerlings and fingerlings (no.20,000; 40-60 mm size) of *Tor khudree* and *Tor mussullah* given by Tata Electric Companies Ltd., Lonavala were stocked in Kerwa. The seed of *Tor khudree* was stocked in Kerwa earlier also by MPSFDC. Kerwa is under the administrative control of Madhya Pradesh Matsya Mahasangh.

The hilly catchment area is favourable for breeding and propagation of mahseer. The rocky-bed, submerged aquatic plants, molluscs and insects are also suited to mahseer culture in Kerwa reservoir. This reservoir provides a suitable habitat for mahseer and it can be developed as a 'mahseer reservoir'. Mahseer is breeding in Kerwa and its growth was also good indicating the suitability of the ecosystem to the fish.

Besides, procuring the seed from Lonavala, some attempts have also been made by the M.P. Matsya Mahasangh to collect the fry and fingerlings from the main river Narmada and the collected seed (no.9000) was stocked in Kerwa. Though the availability of mahseer fry/fingerlings around Hoshangabad has considerably gone down. It was available in plenty in river Narmada before the formation of Tawa dam. The artificial propagation of mahseer by stripping the spawners on experimental basis was also tried by the Mahasangh.

Stocking

The reservoir was stocked with major carp seed @ 127-386 nos./ha/y (av. 260 nos./ha/y) during 1995-96 to 1999-2000 before it was declared as reserved for mahseer. The seed stocked during this period (0.44-1.34 lakh/y) comprised *C. catla* (61.5%), *L. rohita* (17.2%), *C. mrigala* (20.3%) and *C. carpio* (1.0%). In view of the exclusive stocking of mahseer now, the reservoir may be stocked @ 1000 fingerlings/ha/y (100 mm size) with all available species of mahseer including *T. tor, T. khudree and T. putitora.*

Primary production

The GPP (mgC/m^3/h) showed clear seasonality with a very low of 180.2 mg during monsoon to a high of 310.8 mg in post-monsoon months, the average being at 248.8 mgC which could be explained in the light that the post-monsoon peak of plankton, primarily of phytoplankton, was phenomenal in this reservoir. The NPP (mgC/m^3/h) also followed the same trend as of GPP, a low of around 100 mg in monsoon with a high of 170.8 mg in subsequent post-monsoon period. The assimilation efficiency was more or less same without any significant seasonal variations, ranging from 52.8-57.9%, the average being 55.4%, categorising the reservoir a medium productive one. No significant variation in P:R ratio with the seasons was noticed which was in the range 2.1 to 2.4.

Productivity status

Being a small reservoir, Kerwa offers tremendous scope to augment its present fish production. Kerwa has a moderate CA ratio (13). Considering its limno-chemistry of sediment and water,

productivity status assessed through primary production as well as assimilation efficiency and the catchment characteristics, it could be categorised as a medium productive reservoir. Thus, a judicial conversion efficiency of 0.5% GP would give an optimum estimate of TPFY at 545 kg/ha/y. At present, the actual harvest from this small water body is around 72 kg/ha/y which could be enhanced two-three folds easily through suitable manipulations in existing management norms.

Plausible management guidelines

- Ranching of mahseer is a timely and promising measure of rehabilitation of this endangered species.
- Kerwa is best suited to mahseer and offers a tremendous scope for development of its fishery. The fishing should completely be banned for five years.
- In accordance with exclusive mahseer stocking, the reservoir should be stocked with all available species of mahseer particularly *T. khudree, T. putitora* and *T. tor*. The seed could be procured from Tata Electric Companies, Lonavala.
- Attempts should also be made to collect the fry and fingerlings from river Narmada and its tributaries having mahseer for stocking of this reservoir.
- Artificial propagation of the fish by stripping the spawners may also be tried and the induced breeding programme of mahseer may be taken up on the lines of Tata Electric Companies.
- Cage culture of mahseer in Kerwa should also be attempted.

HALALI RESERVOIR

Ecological investigations were carried out in Halali reservoir during 2001-2002. The reservoir also known as 'Samrat Ashok Sagar' was impounded on river Halali – a tributary of river Betwa in district Raisen in 1976, about 40 km from Bhopal. Halali river originates from Chhota Talab, Bhopal. It is known as 'Patra' upto Islamnagar, 'Halali' up to Marmta, 'Bais' thereafter and then joins river Betwa at Vidisha. It is an irrigation project.

Salient morphometric and hydrographic features

Location (District)	Raisen/Vidisha
Year of construction	1976
Basin	Betwa
River	Halali
Latitude	23° 30'N
Longitude	77° 30' E
FRL (m)	458.40
LSL (m)	448.95
Maximum depth (m)	29.5
Mean depth (m)	5.3
Water spread at FRL (ha) A	7712
Catchment area (km^2) C	699
Catchment to reservoir area (C/A)	9.0
Water spread at DSL (ha)	1878
Productive water area (ha)	4795
Gross capacity at FRL (10^6 m^3)	333
Annual inflow (10^6 m^3)	150
Annual water level fluctuations (m)	8
Discharge (Cumecs)	5665
Shore line (km)	65
Shore development	2.1
Volume development	0.54
Av. annual rainfall (mm)	1108

Sediment characteristics

Basin soil is sandy-clay-loam in nature, comprising 60-66% sand, 9-15% silt and 24-28% clay. Rich organic load was encountered in the littoral areas due to heavy infestation of macrophytes dominated by the species like *Potamogeton, Hydrilla, Vallisneria, Ceratophyllum* and *Najas.* Soil reaction was moderately alkaline (pH 7.70-7.78), while littoral soil was having near

neutral pH (7.02). Organic carbon was moderately high, with maximum content during post-monsoon (1.39%) and monsoons (1.25%) with its significant presence in littoral sector (1.52%) of the reservoir. Total-N (%) was in the range 0.036 to 0.056 (mean: 0.044). C/N ratio, an estimator of degree of organic matter decomposition, did not vary widely (25-31) exhibiting a trend of moderate immobilization rather than mineralization. However, available -N (mg/100 g soil) (37.26-56.52, mean: 47.38) was quite favourable for productivity. Available-P (mg/100g) was moderately low (1.10-3.48), might be due to its quicker utilization by aquatic vegetations and fixation by sediment. Free $CaCO_3$ (%) ranged between 2.0 and 2.5. N/P ratio was very moderate (21) in case of profundal zone while it was substantially higher (38) in littoral soil reflecting more available nitrogen in the latter sector.

Sediment characteristics of Halali reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average (Profundal)	Average (Littoral)
Sand (%)	66	61	60	62	55
Silt (%)	9	15	12	12	16
Clay (%)	25	24	28	26	29
pH	7.78	7.74	7.70	7.74	7.02
Sp.cond (mS/cm)	0.246	0.241	0.238	0.242	0.296
Organic- C (%)	1.02	1.25	1.39	1.22	1.52
Total-N (%)	0.036	0.041	0.056	0.044	0.059
C/N	28	31	25	28	26
Avail-N(mg/100 g)	56.52	37.26	48.35	47.38	68.27
Avail-P (mg/100 g)	3.48	1.10	2.19	2.26	1.78
$CaCO_3$ (%)	2.50	2.30	2.00	2.27	1.80

Physico-chemical features of water

Water temperature fluctuated sinusoidally (19.7-29.5°C) keeping parity with air temperature (20.9-30.8°C). Thus, temperature is not a limiting factor for productivity. Euphotic zone extended beyond 4.0 m during pre-monsoon months rendering greater penetration of sunlight upto the bottom waters. Secchi depth was minimum in monsoons (75 cm) and maximum in summer (150 cm). Other physical processes like wind action affects greatly as the reservoir is swept by heavy wind owing to its flattened shape and openness, particularly during monsoons and pre-monsoon. It results in churning of the reservoir, rendering more release of soil nutrients to water phase. This churning also helps in maintaining uniformity of DO level in the entire water column, preventing formation of anoxic bottom even in pre-monsoon also.

Water reaction was moderately alkaline (pH 8.26-8.42, mean: 8.34). Amongst dissolved gases, DO was in the productive range (6.9-8.0 mg/l, mean:7.5) and free CO_2 in surface waters was available year round at 2-5 mg/l while it was slightly higher at the bottom (4-10 mg/l) indicating accelerated decomposition of bottom organic matters - a very productive feature of this reservoir. Total alkalinity was solely contributed by bicarbonate and fluctuated widely to a low of 92 mg/l in monsoons and a high of 142 mg/l in pre-monsoon due to steep fall in water depth in summer. Water was moderately hard as seen from the values of total hardness (88-120 mg/l). Presence of calcium ion was fairly moderate (24.05- 40.08 mg/l) while concentration of magnesium ion was little poor (3.85-6.77 mg/l) in this reservoir.

Due to high water level fluctuation, chloride content increased substantially during pre-monsoon (59.64 mg/l) and post-monsoon (51.12 mg/l), while it was low in monsoons (22.72 mg/l). From the concentration of chloride as observed in this reservoir, it could be concluded that the reservoir is free from local pollution.

Physico-chemical features of water in Halali reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
Temperature (°C)	29.5	28.8	19.7	26.0
Transparency (cm)	150	75	100	108
pH	8.42	8.26	8.35	8.34
Sp. cond.(µS/cm)	280	245	266	264
TDS (mg/l)	182	159	173	171
DO (mg/l)	7.6	8.0	6.9	7.5
Free CO_2 (mg/l)	2.0	5.0	4.0	3.7
Bicarbonates (mg/l)	142	92	128	121
Total alk. (mg/l)	142	92	128	121
Total hardness (mg/l)	120	88	100	103
Ca^{+2} (mg/l)	40.08	24.05	33.66	32.60
Mg^{+2} (mg/l)	4.81	6.77	3.85	5.14
Chloride (mg/l)	59.64	22.72	51.12	44.49
NO_3-N (µg/l)	220	4715	300	1745
PO_4-P (µg/l)	180	71	150	134
Total-P (µg/l)	576	298	500	458
SiO_2-Si (mg/l)	0.80	1.68	0.40	0.96

Nutrient status of water

Amongst essential nutrients, phenomenal presence nitrate-N was registered in monsoons (4715 µg/l), which reduced substantially in the following seasons; in post-monsoon it was 300 µg/l with a lower value in pre-monsoon (220 µg/l) months. The higher concentration of nitrate-N was primarily due to both autochthonous as well as allochthonous sources. The vast littoral areas with heavy detritus load contributed by decomposed and partially decomposed macrophytes are getting exposed during summer, which plays a remarkable role in the supply of nutrients from sediment to water phase, most significantly during first flood received by the reservoir. On the contrary, available-P was comparatively lower than available-N, but its presence also was moderate (71-180 µg/l) as compared to other M.P. reservoirs. Due to quick turnover coupled with utilization by plankton and macrophytes, assessment of phosphate-P will not give clear picture about phosphorus content in a water body. Thus, estimation of total-P content in water definitely provides a conspicuous picture about the dynamics of phosphorus and the productivity. In Halali, total-P (µg/l) was moderately fair to the tune of 298 to 576 (mean : 458). Silicate-Si, the very basis of diatoms was poor (0.40-1.68 mg/l) in this reservoir, not sufficient enough to support a good crop of diatoms.

Biotic communities

Plankton

Plankton population in Halali varied from 282 u/l (0.70 ml/m^3) to 690 u/l (1.06 ml/m^3) during the period under observations. Phytoplankton (90.8%) with Green algae (39.7%), Blue-green algae (20.0%) and Diatoms (31.1%) was predominant in Halali. The occurrence of zoolankton (9.2%) represented by Copepods (6.5%) and Rotifers (2.7%) only was low. Plankton concentration was more during winter. It was also noticed that some of the groups/forms of plankton, not occurring in quantitative estimation but were available in qualitative assessment. The forms are shown below:

Plankton of Halali reservoir

Phytoplankton

Bacillariophyceae	Chlorophyceae	Myxophyceae
Amphora	*Ankistrodesmus*	*Anabaena*
Cymbella	*Chaetophora*	*Anacystis*
Diatomella balfouriana	*Gonatozygon*	*Merismopedia*
Gomphonema	*Hormidium*	*Nostoc*
Navicula	*Pandorina*	*Oscillatoria*
Nitzschia	*Pediastrum*	*Sphaerocystis*
Rhopalodia	*Spirogyra*	*Spirulina major*
Stauroneis phoenicenteron		
Synedra ulna		
Tabellaria		

Zooplankton

Anostraca	Cladocera	Copepoda	Protozoa	Rotifera
Eubranchipus	*Diaphanosoma*	*Cyclops*	*Actinophrys*	*Anuraeopsis*
		Diaptomus		*Brachionus bidentata*
		Mesocyclops		*Chromogaster*
		Nauplii		*Horaella brehmi*
				Hexarthra mira
				Keratella cochlearis
				Keratella valga
				Polyarthra

Macro-benthos

The macro-benthic popualtion of Halali varied from 1739 to 10435 nos/m^2 with an overall average 5594 nos/m^2 during April'01-March'02. Macro-benthos was more in lotic sector as compared to lentic and intermediate sectors.With the lowering of water level during summer a remarkable increase in benthos was observed in March.

Dipterans (46.1 %) were most important followed by Gastropods (42.9 %), Bivalves (6.0%) and Oligochaetes (5.0 %). Dipterans were significant in lotic sector whereas the occurrence of

molluscs was more in lentic and intermediate sectors. The recorded macro-benthic forms are given below.

Dipterans	*Chironomus, Chaoborus, Culicoides,Psychoda,Lumbricillus, Tipula*
Gastropods	*Bellamya bengalensis, Thiara pyramis, Thiara tuberculata, Gyraulus*
Bivalves	*Corbicula, Parreysia, Pisidium*
Oligochaetes	*Lumbriculus, Pristina*

Periphyton

The average density of periphyton fluctuated between 840 u/cm^2 (0.15 ml/cm^2) and 1420 u/cm^2 (0.20 ml/cm^2). Diatoms (74.8 %) were dominant followed by Green algae (23.3 %) and Blue-green algae (1.9 %). Periphyton showed two peaks, the winter pulse in December and the summer in March. The periphytic forms encountered during this period are shown below :

Periphyton of Halali reservoir

Bacillariophyceae	Chlorophyceae	Myxophyceae
Amphora	*Ankistrodesmus*	*Anabaena*
Cymbella	*Chaetophora*	*Merismopedia*
Meridion	*Gonatozygon*	*Spirulina*
Navicula	*Hormidium*	*Stichosiphon*
Nitzschia	*Microspora*	
Rhopalodia	*Spirogyra*	
Synedra		
Tabellaria		

Macrophytes

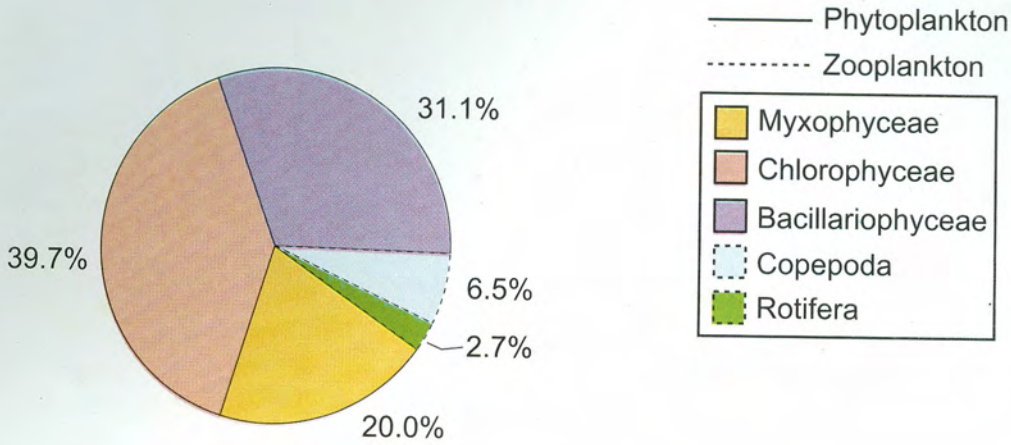
The reservoir exhibited thick vegetation of *Ipomoea* along its banks. Heavy infestation of macrophytes was observed throughout the reservoir. It becomes more visible during summer with low water levels. *Potamogeton crispus* was most abundant. The occurrence of *Hydrilla, Vallisneria,Ceratophyllum* and *Najas* was also observed in Halali reservoir.

Existing management

The fishing rights of this reservoir vest with the M.P. Fisheries Federation. The mode of fish exploitation was contract fishing till 1999-2000. Thereafter, the commercial fishing is being conducted by the State Fisheries Federation itself engaging the local fishermen of Co-operative Societies. The fishermen are paid the fishing charges varying from Rs.4.50 to Rs.14.00 per kg as per the size and category of fish catch. The average income of fishermen was reported to be Rs. 60/head/day. The fish catch is brought and auctioned at Bhopal fish market by the Federation. In cases of glut, the catch is sent to Howrah also.

Quality composition of biotic communities of Halali reservoir (2001-2002)

PLANKTON



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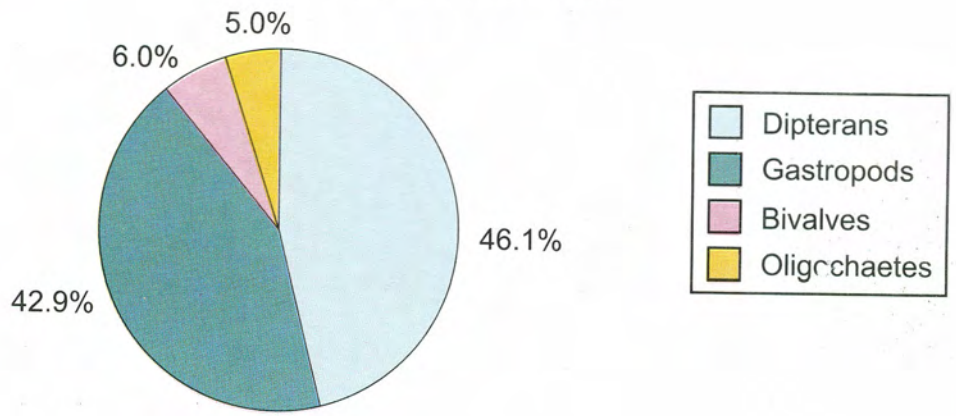
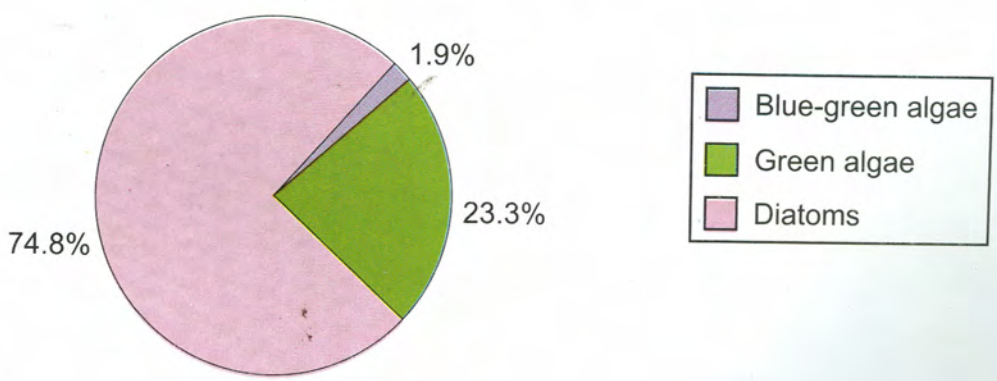
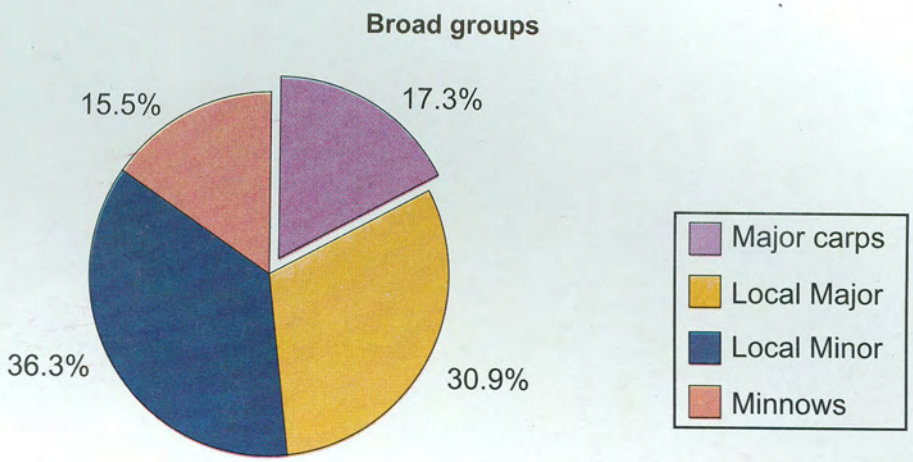
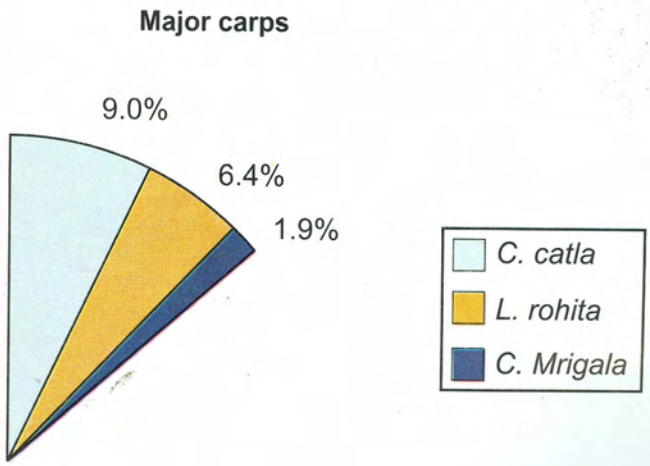


PERIPHYTON



Fish catch composition (%) of Halali reservoir (1996-97 to 2000-01)





A view of Halali reservoir

Fish catch from Halali

A view of Halali reservoir

Fish catch from Halali

Fish yield and catch composition

During 1990-91 to 2000-01, the fish yield of Halali varied from 73.5 t (15 kg/ha) to 350.7 t (73 kg/ha) with an average 193.8 t (40 kg/ha).

The Local minor (36.3%) represented by *L. calbasu* (below 0.5 kg), *N. notopterus, L. bata, L. gonius, C. reba, Mystus* sp. etc. was dominant closely followed by the Local major (30.9%) with *L. calbasu* (above 0.5kg), *A. aor, A. seenghala, W. attu, N. chitala, O. pabda, Mastacembelus* and *Channa* sp. etc. The major carps contributed 17.3% only with *C. catla* (9.0%), *L. rohita* (6.4%) and *C. mrigala* (1.9%). Minnows accounted for 15.5%. It is evident that the indigenous fishes have a strong foothold in this reservoir.

Fishing effort

The simple gill net is the principal gear used for fishing. The mesh bar of these nets varied from 25 to 120 mm. The shore seines during low water levels and the long lines are also used in this reservoir

Seven Fisheries Co-operative Societies are functioning presently in Halali having 364 members belonging to scheduled caste (130), scheduled tribes (35), OBC (128) and general (71).

As seen from the effort data of five years (1996-97 to 2000-01), 55 units/day were employed in commercial fishing of the reservoir. A fishing unit comprises one boat with two fishermen and 20-25 kg of nets.The annual fishing span ranging from 229 to 300 days (Av. 269) was utilised during this period. The catch-per-unit-of-effort (CPUE) was worked out to be 17.4 kg.

Stocking

The reservoir is being stocked regularly with major carps seed @ 63-444 nos/ha (av. 213 nos/ha). But despite this stocking, the sizable fishery of major carps could not be built up in Halali. The retrieval of major carps in relation to stocking was very poor being 2% only.

Primary production

Wide seasonal fluctuations in GPP ($mgC/m^3/h$) were observed in this reservoir ranging from 78.1 to 130.6 mg, a high in pre-monsoon with a very low value in the subsequent monsoon months. The NPP ($mgC/m^3/h$) also followed the same pattern as GPP, more in pre-monsoon (91.2 mg) and the lowest in monsoon (46.8 mg). But assimilation efficiency was very moderate (59.9 - 89.8% av. 63.2%) categorising Halali as a medium productive reservoir. P:R did not vary widely with seasons (2.5-3.3) as the community respiration also fluctuated narrowly (31.3 - 46.9 mg), reflecting autotrophic dominance in this reservoir.

Primary production in Halali reservoir

Parameters	Pre-monsoon	Monsoon	Post-monsoon	Average
GPP ($mgC/m^3/h$)	130.6	78.1	117.2	108.6
NPP ($mgC/m^3/h$)	91.2	46.8	70.3	69.4
Resp. ($mgC/m^3/h$)	39.4	31.3	46.9	39.2
A. E (%)	69.8	59.9	60.0	63.2
P : R	3.3	2.5	2.5	2.8

Productivity status

The annual fluctuation in water level to the tune of 8.0 m is conducive for productivity of the reservoir exposing its vast macrophyte infested littoral areas. It has low C/A ratio (9) with medium fertility of the catchment getting reflected into its moderate limno-chemical features of sediment as well as water. But phytoplankton primary production was moderate (108.6 mgC/m^3/h) with good percentile of assimilation efficiency (63.2%), categorising the reservoir as medium productive one. From a sound conversion efficiency of 0.4% of GP, the TPFY of Halali was estimated at 190 kg/ha/y. At present, a maximum fish yield of 73 kg/ha was realised from this water body. The wide gap between actual and potential yield indicated that 50-60% of TPFY could be achieved through suitable stock manipulations with some changes in present management practices.

The reservoir receives city sewage of Bhopal quite regularly. But no fish mortality has been reported so far due to water pollution. The intake of the city sewage is less as compared to reservoir water storage where the toxicity gets reduced with dilution.

Plausible management guidelines

- Indigenous fishes are significant in Halali having a strong foothold in the reservoir.
- Major carps are poor. The development of major carps seems to be a difficult proposition unless the cat fishes are properly controlled.
- Populations of cat fishes have to be brought down to reduce predatory effect on major carps fishery through intensive fishing.
- Despite regular seed stocking, the sizable fishery of major carps could not be built up in Halali and this seed is going as a waste. In such a situation, the stocking of major carps in Halali needs to be reduced to save the wastage till the cat-fishes are properly controlled.
- Poaching is a serious threat to this reservoir and some effective measures need to be taken in this regard by M.P. Fisheries Federation.
- In a National Workshop on conservation of Indian birds organised by Bombay Natural History Society and the forum for Forestry furtherance at Bhopal in February, 2002, Halali reservoir was also included in the list of some important places in Madhya Pradesh and Chhattisgarh to be declared as the 'Bird Sanctuaries'. If Halali is declared as a 'Bird Sanctuary', the fishing is likely to be banned in this reservoir.
- M. P. Fisheries Department in collaboration with ICAR Institutes should take up cage culture in Halali by leasing out sites to the Fish Farmer's Cooperatives. Joint efforts with funding agencies and Corporations may also be started.

BARGI RESERVOIR

Bargi also known as Rani Awanti Bai Sagar was constructed across river Narmada in 1986 near village Mankhedi in District Jabalpur (M.P.). It is a multipurpose project for irrigation, hydro-power generation, domestic water supply and fish production. Studies on reservoir morphometry, hydrology, soil and water quality, primary production, fish yield, catch structure, biotic communities and fish seed stocking were undertaken during 2002-03.

Salient morphometric and hydrographic features

Latitude	22°56'30" N
Longitude	79°56'30" E
Basin	Narmada
River	Narmada
FRL (m)	422.28
DSL (m)	407.50
Mean depth (m)	14
Maximum depth (m)	59
Water spread area at FRL (ha) A	27697
Catchment area (km^2 C	14536
C/A (Ratio of catchment to area)	53
Productive area (ha)	16649
Gross storage at FRL (mcm)	3920
Av. annual inflow (mcm)	7800
Flushing rate	2 .0
Av. annual outflow (mcm)	4000
Shore line (km)	115
Shore development	1.95
Volume development	0.72
Av. annual rainfall (mm)	1414
Purpose	Multipurpose

Bargi has the privilege of being the first reservoir on river Narmada- the lifeline of Madhya Pradesh.The reservoir is also known as Rani Awanti Bai Sagar. It is a multipurpose project located 43 km south-east of Jabalpur city at Barginagar near village Mankhedi.

The reservoir has a total installed capacity of 90 MW power generation..It serves the irrigation needs of about 4.0 lakh hectare land in four districts *viz.* Jabalpur, Narsinghpur, Satna and Rewa of Madhya Pradesh. It also meets the domestic water demand of about 183 mcm per year of Jabalpur city. Besides, it produces about 300 t of fish every year.

Sediment characteristics

Basin soil is sandy-loam in nature, comprising 68- 76% sand, 15- 22% silt and 9-11% clay. Soil reaction was moderately alkaline (pH 7.65-8.01), while littoral soil was having near neutral pH (7.04). Organic carbon was low with maximum content during monsoon (1.32%) followed by post-monsoon (1.24%). Total-N (%) was in the range (0.019 to 0.083, mean: 0.06). C/N ratio, an estimator of degree of organic matter decomposition, did not vary widely (15-17) and exhibited a productive trend of mineralization. However, available -N (mg/100 g soil) was low

(23.62-36.48, mean: 30.95) probably due to low fertility status of the catchment. But moderate presence of available-P (mg/100g) was noticed (5.25-10.84). Free $CaCO_3$ (%) ranged from 1.2 to 1.8. N/P ratio was very low (3.9) in case of profundal zone in this reservoir. Heavy metals in sediment (mg/kg) were encountered on an average at Zn (104.64), Cu (108.74), Cd (4.14), Pb (10.88) and Cr (45.61) while predominant concentration of Mn (1149.37) was found in this reservoir.

Sediment characteristics of Bargi reservoir

Features	Pre-monsoon	Monsoon	Post-monsoon	Range	Average
pH	7.65	7.68	8.01	7.65-8.01	7.78
Sp. cond. (mS/cm)	0.14	0.202	0.186	0.140-0.202	0.176
Organic -C (%)	0.23	1.32	1.24	0.23-1.32	0.93
Total - N (%)	0.019	0.078	0.083	0.019-0.083	0.06
C/N	12	17	15	17-Dec	15
Avail-N (mg/100g)	23.62	32.76	36.48	23.62-36.48	30.95
Avail-P (mg/100g)	5.25	8.68	10.84	5.25-10.84	8.26
$CaCO_3$ (%)	1.8	1.2	1.6	1.20-1.80	1.5

Physico-chemical features of water

Water temperature fluctuated sinusoidally (20.4-29.7°C) keeping parity with air temperature (20.2-32.0°C).The temperature is not a limiting factor for productivity. Euphotic zone did not extend beyond 2.0 m even during pre-monsoon months. Secchi depth was minimum in monsoons (12 cm) and maximum in summer (60 cm). Other physical processes like wind action matters greatly as the reservoir is swept by heavy wind owing to its flattened shape and openness, particularly during monsoon and pre- monsoon, resulting in churning of the reservoir to a great extent. This churning also helps in maintaining uniformity of DO level in the entire water column, preventing formation of anoxic bottom even in pre-monsoon also.

Water reaction was moderately alkaline (pH 8.04-8.40, mean: 8.25). Amongst dissolved gases, oxygen (DO) was in the productive range (6.5-8.1 mg/l, mean: 7.2) and free CO_2 in surface water was available year round at 4-8 mg/l while it was slightly higher at the bottom (6-13 mg/l) indicating accelerated decomposition of bottom organic matter -a very productive feature of this reservoir. Total alkalinity (TA) was solely contributed by bicarbonate and fluctuated widely to a low of 68 mg/l in monsoon and a high of 112 mg/l in pre-monsoon due to steep fall in water depth in summer. Water was moderately hard as seen from the values of total hardness (60-96 mg/l). Presence of calcium ion was moderate (16.03- 27.25 mg/l) while concentration of magnesium ion was little bit poor (4.84-6. 77 mg/l) in this reservoir. Chloride content did not vary substantially (17.04-18.46 mg/l). From the concentration of chloride as observed in this reservoir, it could be concluded that the reservoir is free from local pollution. Heavy metals in water (µg/l) did not show any sign of pollution in this reservoir; Zn, Cu, Cd, Cr and Mn were registered to the tune of 9-24, 9-18, 2- 7, 13-28 and 52-93 respectively, while Pb concentration was noticed below detectable limit.

Quality composition of biotic communities of Bargi reservoir (2002-2003)

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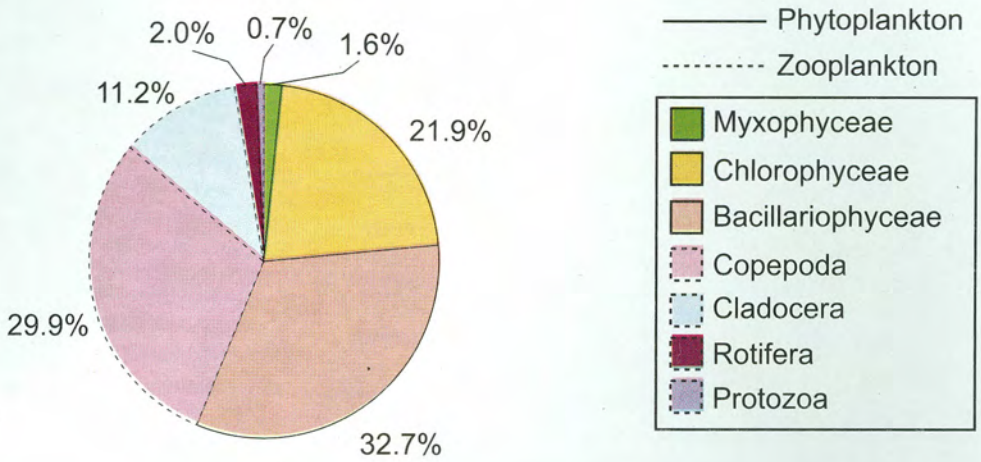

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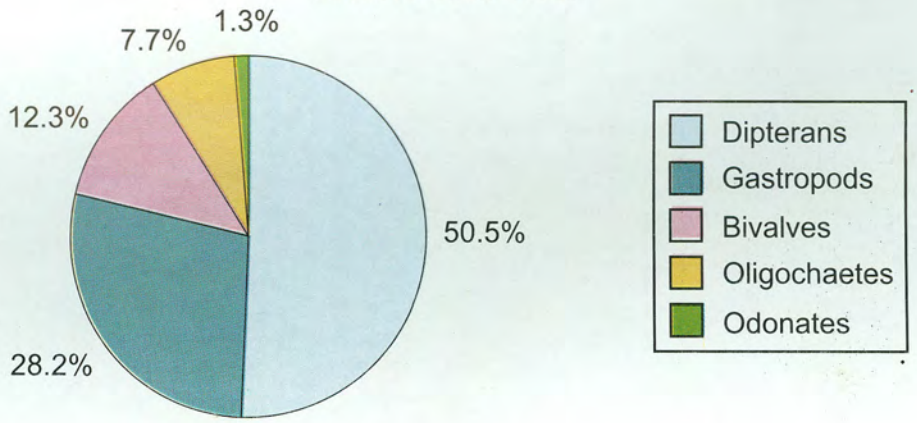
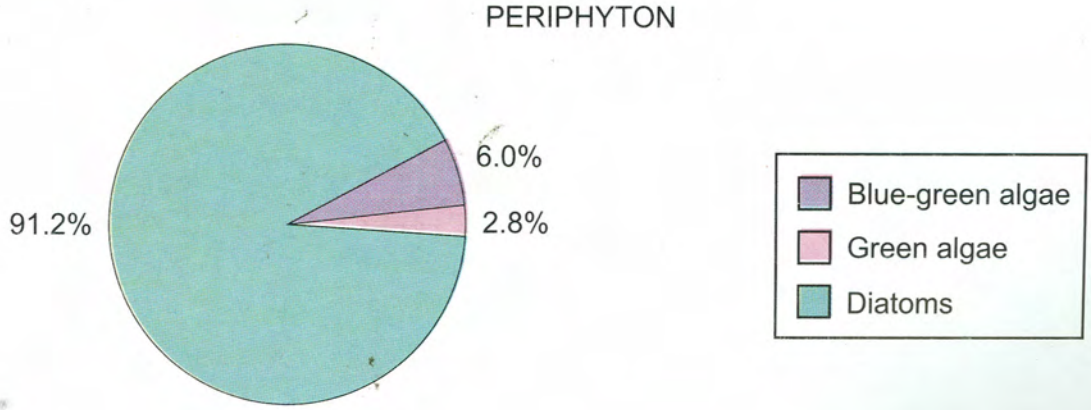
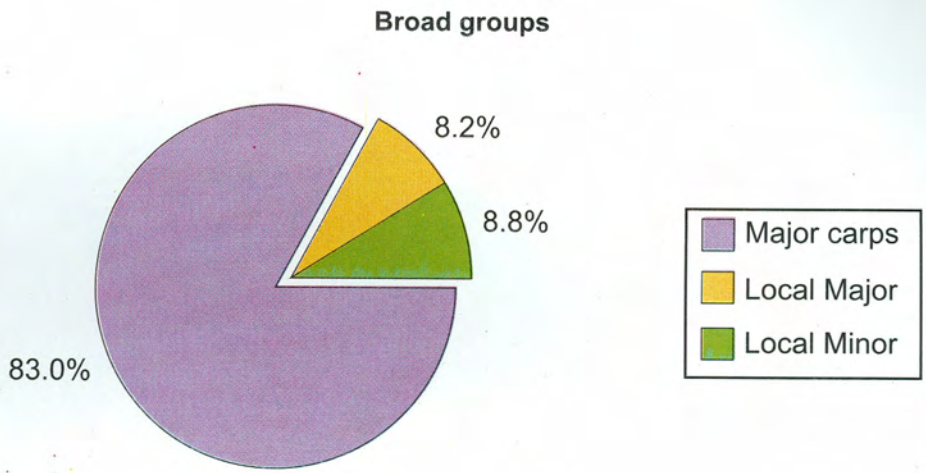
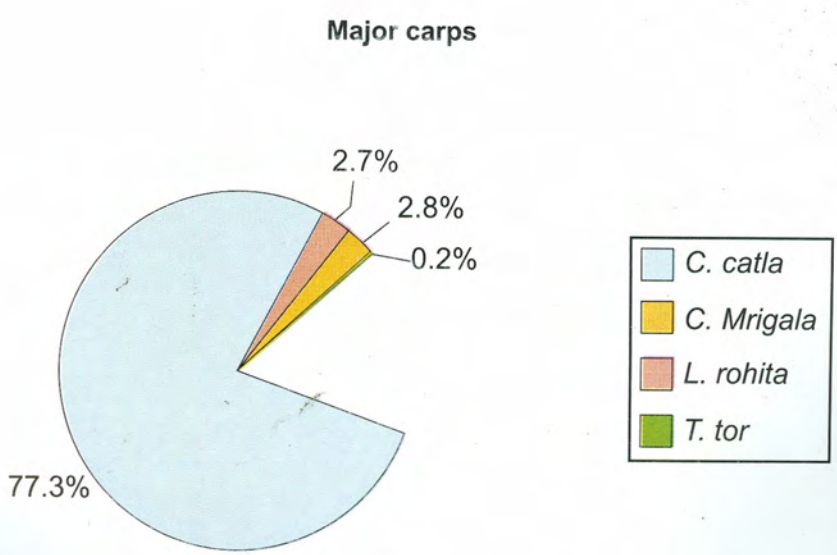


PERIPHYTON



Fish catch composition (%) of Bargi reservoir (2002-03)





A view of Bargi reservoir

Fish catch from Bargi reservoir

Physico-chemical features of water in Bargi reservoir

Features	Pre-monsoon	Monsoon	Post-monsoon	Range	Average
DO (mg/l)	6.5	6.9	7.4	6.5-7.4	6.93
CO_2 (mg/l)	8	6	4	4.0-8.0	5.6
pH	8.40	8.04	8.31	8.0-8.4	8.25
Sp. Cond. (µS/cm)	180	125	140	125-180	148
Tot. Alk (mg/l)	112	68	76	68-112	85
TH (mg/l)	96	60	60	60-96	72
Ca^{+2} (mg/l)	27.25	16.03	16.03	16.0-27.3	19.77
Mg^{+2} (mg/l)	6.77	4.84	4.84	4.8-6.8	5.48
Cl^- (mg/l)	17.04	17.04	18.46	17.0-18.5	17.51
NO_3-N (µg/l)	47	469	314	47-469	277
PO_4-P (µg/l)	24	26	8	8 - 29	19
Tot- P (µg/l)	76	125	40	40-125	80
SiO_2-Si (mg/l)	5.37	8.46	4.12	4.1-8.5	5.98

Nutrient status of water

Amongst essential nutrients, noticeable presence of nitrate-N was registered in monsoon (469 µg/l), which reduced substantially in the subsequent seasons; in post-monsoon it was 314 µg/l with the lowest in pre-monsoon (47 µg/l) months. The higher concentration of nitrate-N was primarily due to both autochthonous as well as allochthonous sources. On the contrary, available-P was very low (8-26 µg/l) as compared to other M.P. reservoirs. Due to quick turnover coupled with utilization by plankton and macrophytes, assessment of phosphate-P will not give clear picture about phosphorus content in a water body. Thus, estimation of total-P content in water definitely provides a conspicuous picture about the dynamics of phosphorus and the productivity. In Bargi, total-P (µg/l) was found in the range of 40 to 125 (mean : 80). Silicate-Si, the very basis of diatoms was moderate (4.12- 8.46 mg/l) in this reservoir, sufficient enough to support a good crop of Bacillariophyceae.

Biotic communities

Plankton

Plankton population varied from 99 to 266 u/l (0.35-0.70 ml/m^3). Phytoplankton (56.2%) was contributed by Diatoms (32.7%), Green alage (21.9%) and Blue-green algae (1.6%). Among zooplankton (43.8%), Copepods (29.9%) were important followed by Cladocerans (11.2%), Rotifers (2.0%) and Protozoans (0.7%) .The following planktonic forms were recorded:

Phytoplankton

Bacillariophyceae		Chlorophyceae	Myxophyceae
Gyrosigma	*Surirella,*	*Gonatozygon*	*Microcystis*
Navicula,	*Synedra,*	*Pediastrum simplex,*	

Zooplankton

Cladocera	Copepoda	Protozoa	Rotifera
Ceriodaphnia cornuta	*Cyclops,*	*Difflugia*	*Keratella*
Diaphanosoma	*Diaptomus,*		
	Nauplii		

Macro-benthos

The standing crop (nos/$m^{2)}$ of macro-benthos of Bargi varied from 478 to 3957 (av.2181). The concentration was more in littoral zone (67.8%) than sub-littoral (15.9%) and profundal (16.3%) zones of the reservoir. Dipterans (50.5%) were important followed by Gastropods (28.2%), Bivalves (12.3%), Oligochaetes (7.7%) and Odonates (1.3%). The following macro-benthic forms occurred during the course of the study:

Gastropods	*Bellamya, Thiara, Gyraulus, Lymnaea*
Bivalves	*Parreysia, Corbicula, Pisidium*
Dipterans	*Chironomus, Chaoborus, Culicoides*
Oligochaetes	*Tubifex*
Odonates	*Anax*

Periphyton

Periphyton varied from 44 to 960 u/cm^2 (0.02-0.10 ml/cm^2) during the period under report. Diatoms (91.2%) were pre-dominant with poor occurrence of blue-green algae (6.0%) and green algae (2.8%).

Periphyton of Bargi reservoir

Bacillariophyceae	Chlorophyceae	Myxophyceae
Amphora,	*Ankistrodesmus*	*Phormidium*
Cocconeis,	*Gonatozygon,*	
Fragilaria,		
Gomphonema,		
Navicula,		
Synedra,		

Macrophytes

Macrophytes were poor in Bargi reservoir. The occurrence of *Hydrilla, Vallisneria* and *Potamogeton* was observed.

Fishery management

The fishery management of the reservoir is under the control of Madhya Pradesh Matsya Mahasangh, the erstwhile M.P. Fisheries Development Corporation. In the initial stage, the management was on departmental basis. Later, the auction system was adopted till 1994. Thereafter, the management came under the control of an Apex Federation of Fishermen Co-

operatives which continued till 2000. A Fisheries Federation of 54 Cooperative Societies from Jabalpur, Mandla and Seoni was formed in 1994 and got the fishing rights of this reservoir for five years on royalty basis. But due to some conflict on the royalty payment, the Government ceased the fishing rights of the Federation from 2000. Presently, the M.P. Matsya Mahasangh is undertaking the commercial fishing with the local fishermen of the Cooperative Societies. The fishermen are paid the fishing charges @ Rs.14.50 per kg and 0.50 per kg as deferred wages for the closed season.

The mesh regulation is strictly followed in Bargi reservoir with minimum mesh-bar size being 50 mm in the commercial fishing. A fishing effort of 125 units/day was employed; one unit comprises 1 boat, 2 fishermen and 20 kg of nets. The CPUE was worked out to be 12 kg.

Fish yield and catch structure

During 1997-98 to 2001-02, the fish production of Bargi varied from 173.3 t (10.4 kg/ha) to 493 5 t (29.6 kg/ha) with an average 304.0 t (18.3 kg/ha). The reservoir has given a maximum production of 649.1 t (39.0 kg/ha) in 1995-96.

Major carps (83.0%) were the most important contributed by *C. catla* (77.3%), *C. mrigala* (2.8%), *L. rohita* (2.7%) and *T. tor* (0.2%). Local major (major cat fishes) and local minor (small carps & cat fishes) accounted for 8.2% and 8.8% respectively.

Stocking

The reservoir is being stocked regularly with major carp seed. The stocking rate was 191 fingerlings /ha with *C. catla* (40%), *L. rohita* (30%) and *C. mrigala* (30%) during 1989-2002.

Primary production

Wide seasonal fluctuations in gross primary production (GPP, $mgC/m^3/h$) were registered in this large reservoir varying between 46.88 and 93.75 mg; a high in pre-monsoon and a very low value in the subsequent monsoon months. Net primary production (NPP, $mgC/m^3/h$) also followed the same trend as GPP, more in pre-monsoon (52.08 mg) and the lowest in monsoon (23.44 mg). Assimilation efficiency was very moderate (50.0 -55.6%, mean: 53.7%), indicating Bargi as a low to medium productive reservoir. P:R did not vary widely with seasons (1.8-2.2) though the community respiration varied moderately (23.44- 41.67 mg), reflecting autotrophic dominance in this reservoir.

Productivity status

The annual fluctuation in water level to the tune of 18-24 m is a boon for productivity of this big reservoir, exposing its vast littoral areas. It has a moderate C/A ratio (53) with low fertility of the catchment, getting reflected into its low to moderate limno-chemical features of sediment as well as water. Same was also reflected in phytoplankton primary production with average gross production at 70.31 $mgC/m^3/h$ and moderate percentile of assimilation efficiency (53.70 %), categorising the reservoir as low to medium productive one. From a sound conversion efficiency of 0.2% GP, the targeted potential fish yield (TPFY) of Bargi was estimated at 65 kg/ha/y. At present, fish yield is of very low order (av. 18 kg/ha/y) of this water body. The wide gaps between actual and TPFY indicated that 50-60% of TPFY could be

achieved through suitable stock manipulation with some changes in present management practices.

Plausible management guidelines

- ❖ Full available fishing span approximately about 300 days needs to be properly utilized for commercial exploitation to obtain maximum fish production from the reservoir.

- ❖ Present intensity of fishing effort (125 units/day) also requires to be increased to 150 units/day for enhancing the fish yield.

- ❖ Mesh regulation with a ban on gill nets below 50 mm bar may be strictly followed in commercial fishing of this reservoir.

- ❖ Studies revealed that the stocking rate may also be raised to 250 fingerlings/ha with a bigger size of stocking material (75-100 mm).

- ❖ Co-operative movement in reservoirs of Madhya Pradesh was first initiated from Bargi with the success story and paid alround dividends to all concerned also. But it had a set back when it was discontinued recently. It needs to be revived and given back to the Co-operative Federation again in view of the State Govt. plan to involve and encourage the cooperatives in the development of reservoir fisheries.