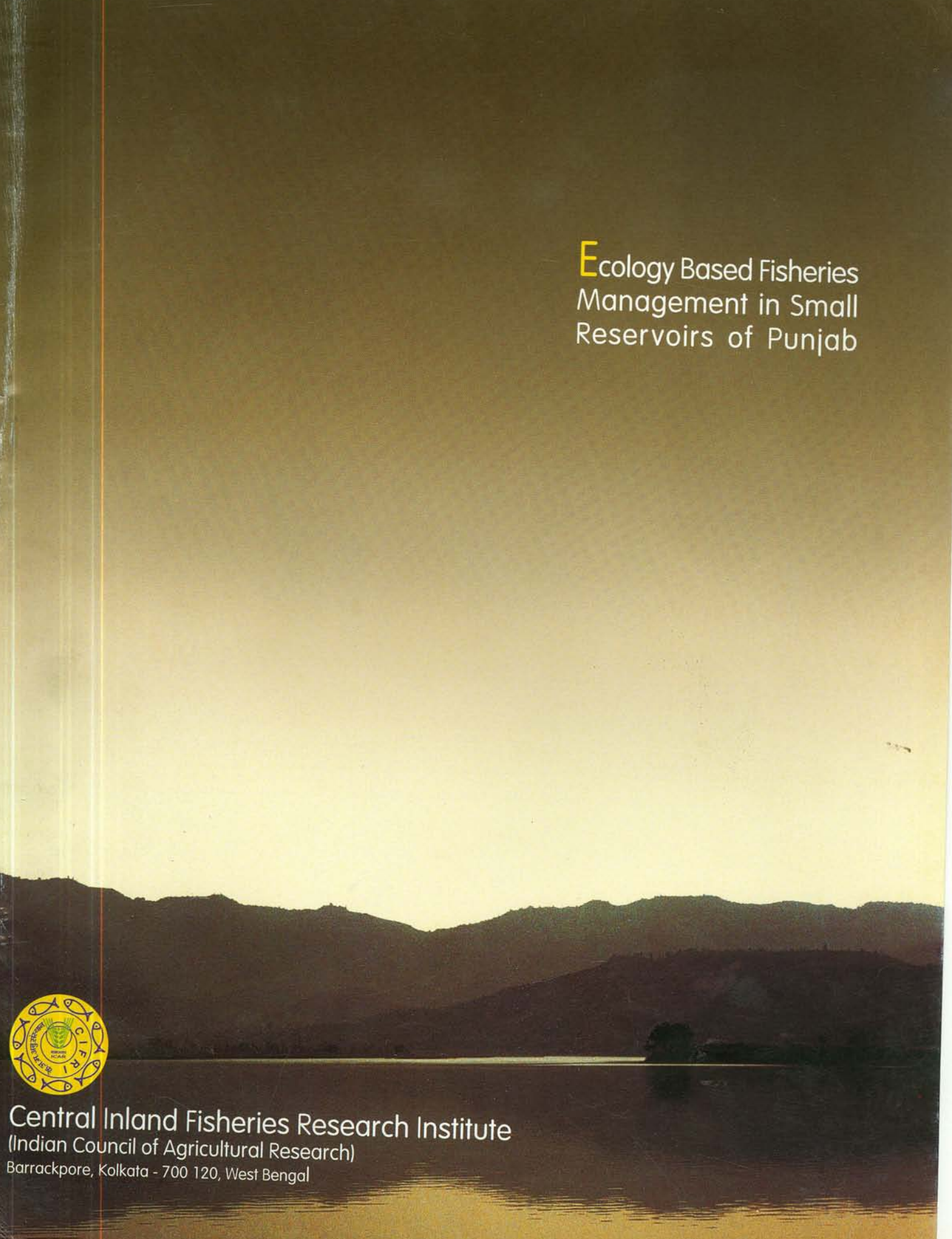
Ecology Based Fisheries Management in Small Reservoirs of Punjab



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FOREWORD

Reservoirs form the most important inland fishery resources of India with immense potential to enhance the nation's inland fish production. Small reservoirs which are primarily based on environment enhancement culture system can go a long way in upliftment of rural poor folk by providing them protein rich diet and rural employment. Keeping this in view scientists and research workers of CIFRI have investigated ecology and fisheries of small reservoirs of Punjab. I hope the results presented will go long way to develop similar water bodies in the State for fisheries development. The investigations have brought out important limnological features of Dholbaha, Janauri, Maili and Nangal reservoirs with useful recommendations for development of fisheries therein.

I am hopeful that this Bulletin will be of great help in formulating guidelines for scientific management of small reservoirs in the state of Punjab.

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INTRODUCTION

Ever since independence, the main focus of developmental activities in India has been on harvesting the river waters for irrigation and hydro-electric generation. The result is formation of large number of small, medium and large river valley projects. The direct result of these developmental activities is the formation of a large Number of man made reservoirs. Small reservoirs support a variety of fish population, which help in combating malnutrition in our poor rural folk and generating employment. Productivity of reservoir depends to a large extant on number of variables present in the ecosystem. Thus a database on abiotic and biotic parameters and fish stock of water body is an essential prerequisite for management of water resources.

Punjab state has got 10 small reservoirs & one medium reservoir, namely Dholbaha , Mailli, Janauri, Salrian, Chohal Mangrowal in Hosiarpur district and Nangal in Roopnagar districts, in addition Saha Nahar Barrage in Hoshiarpur and Harike in Amritsar district. Of these detailed investigations were carried out in Dholbaha, Janauri and Mailli and Nangal Lake. Dholbaha, Janauri and Mailli reservoirs are mainly for flood control and irrigation purpose and are located in lower Shiwalik ranges, where as Nangal reservoir is meant for irrigation and hydroelectric power generation.

Sampling Procedure

Samples pertaining to limnobiological parameters were collected once each in summer (March-June,1997), post-monsoon (Sept.- Oct., 1996) and winter (Jan.- Feb.,1997) seasons. The physico- chemical parameters of water were determined following the standard method given in APHA (1985). The analysis in respect of biological parameters were done as described by Jhingran *et al.*, (1969).

1. DHOLBAHA RESERVOIR

1.1 Location and Morphometry

Dholbaha dam is a irrigation and flood control project, constructed in the year 1986 on Dholbaha choe in Hoshiarpur district for irrigation and flood control with the aid from World Bank under Kandi Watershed and Area Development Programme. The dam is located downstream of confluence of Kukanet and Buhera khads. It is situated at about 30 Km awaay from Hoshiarpur town, at latitude 31.5° and longitude 77°.

Dholbaha dam is an earth fill dam consisting of a central impervious core, protected by previous shell zones on its upstream. A principle spillway consisting of 2 barrel of 200 x 2575 mm at an elevation 417.0m, combined with an overflow auxiliary spillway with its creast fixed at elevation 424.0 m to cater for design flood of 16,000 cusecs have been provided.

The Reservoir has a total catchment area of 56/14 km^2 with a gross storage capacity of 1091 ha m. The water spread area of the reservoir is 57 ha at FRL. The reservoir has a maximum depth of 18.5 m. The salient morphometric features are as follows :-

1. Year of completion : 1986
2. Purpose : Irrigation and flood control
3. Dam details :
   i) Type : Earth Fill dam
   ii) Top level : 430.5 m
   iii) Height of Dam above choe bed : 38.83 m
   iv) Length at top : 358 m
   v) Width at top : 10 m
   vi) Maximum width at base : 205 m
   vii) Maximum reservoir level : 427.0 m
   viii) Normal reservoir level : 417.0 m
   ix) Dead storage level : 403.5 m
   x) Catchment area : 56.14 km^2
   xi) Water spread area at FRL : 57 ha
   xii) Gross storage capacity : 1091 ha m
   xiii) Live storage capacity : 984 ha m
   xiv) Dead storage capacity : 107 ha m
   xv) Discharge : 1.22 cucecs

1.2 Meteorological and Hydrographical observations

Dholbaha reservoir is mainly rainfed with a catchment area of 56.14 sq. km. The average annual precipitation is reported to be 97.9 cm. The normal reservoir level is 417.0 m at FRL and the dead storage level is 405.0 m. The average water fluctuation in the reservoir is 6.33 m.

1.3 Limnology and productivity

Physico-chemical characteristics of soil :- The bottom soil was alkaline in reaction (pH 7.1) and was sandy (42.3 to 53.4%) in texture (Table 1). The percentage of clay increased from 16.0 to 29.3% during post-monsoon months due to influx of rain water from the catchment area. The overall high percentage of sand indicated poor water retention capacity of the soil. Organic carbon (0.32 to 0.36%) and available phosphorus (4.8 to 4.9 mg/100g) indicated poor quality of soil. The energy brought in through the allochthonus source is inadequate as is evident by poor organic matter in its soil. The energy stored in the reservoir is thus limited only through solar radiation and autochthonus source.

Table:1 Physico-chemical characteristics of soil of Dholbaha Reservoir.

Parameters	Pre-monsoon	Post-monsoon
Sand (%)	53.4	42.3
Silt (%)	30.6	28.4
Clay (%)	16.0	29.3
pH (%)	7.1	7.1
Organic carbon (%)	0.36	0.32
Free CO_3 (%)	0.69	0.62
Available phosphorus (mg/100g)	4.90	4.80
Available nitrogen (mg/100g)	55.30	50.90
Specific conductivity (µmhos/cm)	215.3	242.5

Physico-chemical characteristics of water :- The minimum temperature was recorded in winter (13.0°C) while maximum in the month of May (30.0°C; Table 2). Hydrogen-ion-concentration varied between 6.2 to 7.0. The minimum values were in winter and maximum was in post-monsoon. The narrow range of fluctuation in pH however indicated a strong buffering capacity of the reservoir, which did not allow pH to change much. Transparency fluctuated from 50 to 108 cm. The low values recorded during summer could be due to winds of high velocity. The high values were in winter could be due to low wind action. Dissolved oxygen varied between 4.4 and 6.56 ppm. Free carbon dioxide was nil in the reservoir during summer and winter months whereas it appeared at the rate of 20.0 ppm during post-monsoon months. The seasonal variations in alkalinity values in prominent with the minimum values in post-monsoon and maximum values in winter months. It ranged from 62.0 to 216.0 ppm. The water bodies having total alkalinity above 90.0 ppm are generally considered conducive to high fish productivity.

Based on calcium concentration varying between 22.45 and 36.87 ppm, the reservoir water can be said to be of productive nature. Magnesium content was also of high order, ranging from 6.87 to 9.85 ppm. Total hardness ranged from 96.0 to 120.0 ppm. Chloride values fluctuated between 11.36 to 14.2 ppm and were of medium class. Organic matter is an important parameter reflecting the productive nature of water. Its values ranged between 1.6 to 8.0 with an average of 4.7 ppm. More than 1.0 ppm of organic matter is considered to be indicative of high productive potential . High values of specific conductivity varying between 236.0 and 364.0 µmhos/cm indicated the productive state of the reservoir (Table 2).

A perusal of the limno-chemical parameters like total alkalinity (62-216 ppm), calcium (22.45-36.87 ppm) and specific conductivity (236.0-364.0 µmhos/cm) suggest medium productivity potential of Dholbaha reservoir. The rich water quality reflected the transport of allochthonous dissolved nutrients and their leaching into the trophic cycling system.

Table:2 Physico-chemical characteristics of surface water of Dholbaha Reservoir.

Parameters	Ranges	Average
Water temperature	130-3-.0	23.7
Transparency	50.0-108.0	86.4
pH	6.2-7.0	6.7
Dissolved oxygen (ppm)	4.4-6.5	5.3
Free CO_2 (ppm)	Nil-20.0	6.7
Bicarbonate (ppm)	62.0216.0	150.7
Dissolved organic matter (ppm)	1.6-8.0	4.7
Hardness (ppm)	96.0-120.0	109.3
Calcium (ppm)	22.45-36.87	29.39
Magnesium (ppm)	6.87-9.05	8.86
Chloride (ppm)	11.36-14.2	12.3
Sp. conductivity (µmhos/cm)	236.0-364.0	287.3

Thermal and chemical stratification :- Depth-wise temperature of water (Table 3) recorded during winter showed isothermal condition in the reservoir with uniform temperature of 13°C at surface to 8 m depth. Depth-wise analysis of dissolved oxygen, free CO_2, total alkalinity and specific conductivity did not show marked variation (Table 3).

Table:3-Depth profile of Dholbaha Reservoir.

Depth	Water temp. (°C)			pH			D.O (ppm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	28.0	13.0	30.0	7.0	6.2	6.9	5.1	4.4	6.6
2	-	13.0	-	-	6.9	-	-	4.4	-
4	-	13.0	-	-	7.2	-	-	4.4	-
6	-	13.0	-	-	7.3	-	-	4.0	-
8	-	13.0	-	-	7.4	-	-	4.0	-

Depth	Free CO_2 (ppm)			Total Alkalinity (ppm)			Sp. conductivity (µmhos/cm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	20.0	Nil	Nil	62.0	216.0	274.0	236.0	262.0	364.0
2	-	Nil	-	-	220.0	-	-	265.0	-
4	-	Nil	-	-	220.0	-	-	268.0	-
6	-	Nil	-	-	222.0	-	-	270.0	-
8	-	Nil	-	-	224.0	-	-	270.0	-

Primary productivity :- The gross primary carbon production varied from 91.7 to 155.0 with an average of 115.6 mgC/m²/hr the net production ranged between 31.8 and 105.0 (av. 59.5) mgC/m²/hr. Thus the expected fish yield is 98 kg/ha. Taking an annual average growth rate of 0.50 kg for each of the species for carps stocked and giving an allowance of 40% loss in terms of escapement of fingerlings through irrigation channel and overflowing spillway, the stocking rate will be 270 numbers per hectare.

1.4 Biotic Communities

Plankton:- The plankton population ranged 375 u/l in post-monsoon (Fig.2). On an average phytoplankton formed 81.7%of the total plankton (Table 4). The qualitative description of the plankton is depicted in Table 5. Bacillariophyceae was the most dominant group among phytoplankters and on an average it formed 58.1%of the total plankton population. The major pulse was observed during post-monsoon (76.9%). The forms observed were *Diatoma, Gyrosigma, Synedra ulna, Fragilaria, Pinnularia, Navicula, Eunotia, Tabellaria, Mastogloia, Cymbella* and *Amphora*. Chlorophyceae formed 16.7% of the total planktonic population and was represented mainly by *Troschia, Rhizoclonium and Pediastrum*. Maximum density of this group was observed in winter (20.4%) and minimum in post-monsoon(9.6%).The percentage of myxophyceae fluctuated from 7.4 in winter to 13.3% in summer. *Oscillatoria* followed by *Nostoc* were the dominant forms observed. The abundance of pollution indicator species such as *Pediastrum* under chlorophyceae; *Cymbella, Fragilaria* under Bacillariophyceae and *Oscillatoria, Nostoc* under myxophyceae were less encountered which indicates the presence of more No. of clean water indicative species in the phytoplancton community. Zooplankton were mainly dominated by Copepods *(Cyclops, Diaptomus and Nauplii*) which constituted10.8% of the total plankton. Rotifers (*Notholca)* formed 4.4% of the plankton.

Table: 4 Composition of Plankton in Dholbha Rservoir.

Period	u/l	%of different groups			
		Chlorophyceae	Myxophyceae	Bacillariophyceae	Rotifers
Sep-Oct, 96	496	9.6	76.9	-	-
Dec-Jan	442	20.6	7.4	57.4	-
May·97	375	20.0	13.7	40.0	13.0

Table: 5 List of Plankton of Dholbha Reservoir.

Bacillariophyceae -	*Tabellaria, Mastoglioa, Fragilara, Coconies, Naviculla, Melosira, Neidium, Nitzshia, Amphora, Gomphonema,Cymbella, Synedra, Diatoma, Eunotia, Calonies,Gyrosigma,Planktospharia.*
Chlorophyceae	*-Troschia, Rhizoclonium, Psdiastrum, Characium, Planktosphaeria.*
Dinophyceae	*-Cystodinium.*
Myxophceae	*-Nostoc,Oscillatora*
Protozoa	*-Actinosphaerium*
Roftifera	*-Notholca.*
Cladocera	*-Daphina.*
Copepoda	*-Cyclops, Diaptomus, nauplii.*

Periphyton :- Periphyton population ranged from 1843 u/cm² in post-monsoon to 2425 u/cm²in winter(Fig. 2). Bacillariophyceae (73.7%) dominated over myxophyceae (14.8%) and chlorophyceae (8.1%; Table 6). Bacillariophyceae was quantitatively and qualitatively the richest among the algae. It was represented by Fragilaria, Amphora, Amphipleura, Diatoma, Rhicosphenia, Surirella, Caloneis, Cymbella, Navicula and Gomphonema. Chlorophyceae was comprised of Characium and Cosmarium. Myxophyceae flora were consisted of Amphithrix and Schzothrix. Difflugia was the sole representative of protozoans.

Table: 6 Composition of Periphyton in Dholbha Reservoir.

Period	u/cm²	% of different groups		
		Chlorophyceae	Myxophyceae	Bacillariophyceae
Sep. Oct 96	1843	5.3	10.5	84.2
Oct,96	2425	4.0	24.0	72.0
Dec-Jan.	1940	15.0	10.0	65.0
May·97				
Average	2069	8.1	14.8	73.7

Macrobenthos:-The production of macrobenthic fauna was 50 u/m²in summer; 450 u/m² in post-monsoon and 750u/m² in winter. On an average, the standing crop was estimated as 750u/m² (Table 7). Mosquito larvae dominated the fauna (74.4%) followed by *Chaoborus* larvae (14%). Group wise distribution detail is given in Table 7. Minimum concentration of macrobenthos observed in summer months may be due to absence of weeds which provides shelter and foothold to larvae. Maximum concentration of benthos were recorded in post-monsoon. The poor abundance of benthos among biotic communities and the absence of macrophytes may be ascribed to limited concentration of organic matter in soil.

Table: 7 Composition of Benthos in Dholbha Reservoir.

Species	Summer		Post-monsoon		Winter		Average	
	u/m2	gm/m2	u/m2	gm/m2	u/m2	gm/m2	u/m2	gm/m2
Molluscs	50	neg	100	0.26	200	0.52	83	0.26
Chaoborus	-	-	-	-	300	0.36	100	0.12
Mosquito larvae	-	-	1350	neg	250	neg	533	neg.

Macovegetation:- The reservoir has no submerged, emergent or free floating aquatic vegetation in any of the season. However, marginal area, have got thin growth of *Ipomea* which should be destroyed to avoid degradation of the lake.

1.5 Biology of fishes

Length-weight relationship:- The length-weight relationship of the following two species of fish from the reservoir were derived as follows :-

i) *C. carpio* $\text{Log } W = 0.8905 \text{ Log } L^{0.0167}$

$W=0.9622\ L^{-0.8905}$

ii) *L. rohita* $\text{Log } W=2.8479 \text{ Log} L^{4.7046}$

$W=1.9738 \times 10^{-5} L^{-2.8479}$

Stocking

The reservoir has been stocked every year by the Department of Fisheries, Punjab and the year-wise stocking figures available are as follows:-

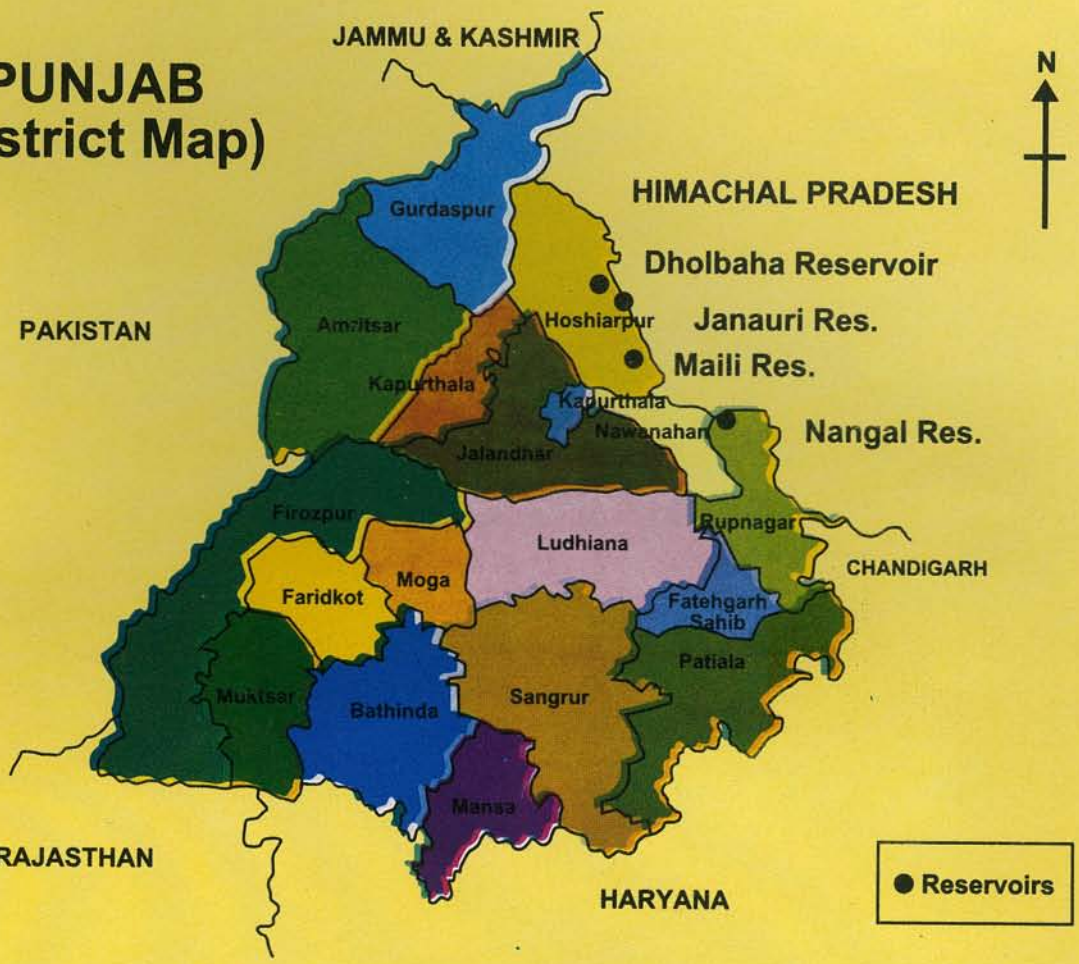
Year	Common carp	Grass carp	IMC	Unknown spp.	Total
1990-91	60,000	-	-	-	60,000
1991-92	-	-	-	25,000	25,000
1992-93	18,000	15,000	-	-	33,000
1993-94	-	-	40,000	-	40,000
1994-95	29,500	-	-	-	29,500
1995-96	75,000	-	-	-	75,000
1996-97	98,000	-	50,000	-	1,48,000

There is no fish farm adjoining to the reservoir for rearing fish seed prior to stocking in the reservoir. However, there is a fish farm at Hariana town. On an average, a total of 58,643 fish seed have been stocked in the reservoir every year based on the figures for last seven years. The rate of stocking is therefore 1028 ha/yr dominated by *C. carpio* (68.33%) followed by IMC (21.92%). Continued stocking by the Fisheries Department did not have a desired impact on the fishery probably due to the small size at the time of stocking and escapement along with outflow through spillway.

1.6 Commercial fishing

There are about seven reservoirs namely Dholbaha, Janauri, Maili, Salerian, Chohal, Damsal and Mangrowal in Kandi tract of Hoshiarpur district. The Punjab Govt. has so far notified only Dholbaha, Janauri and Maili for fishing activities and all the three reservoirs are situated in drought affected areas. These notified reservoirs

PUNJAB
(District Map)



are auctioned annually through public auction for a period from 1st August to 31st July with close season of two months (1st July to 31st August. Fishing is regulated under Punjab Fisheries Act 1985. The present fishing contract for all the three reservoirs is with single contractor for Rs. 38,000/-.

There is no exclusive fishermen village surrounding the reservoir. There are two fishing parties engaged by the contractor. Each fishing party consists of four wooden boats and five fishermen belonging to North-Eastern states. Contractor provides nets and boats. Fishermen use only nylon gill-nets with mesh-bar varying from 38 to 150 mm. Fishing in reservoir is done for 20 days in a month due to shifting of the fishing parties to other two reservoirs for fishing. The exploitation of the reservoir invariably becomes difficult due to submerged tree trunks, old buildings and houses which prevent proper operation of the gill-nets. Large numbers of fishes escape from the reservoir through spillway during discharge of excess flood water.

Observations on the fish spectrum of the reservoir showed absence of natural fishery. The fish catch is totally composed of culturable fishes which are stocked by the Department of Fisheries, Punjab. The commercial fishes in the reservoir in order of their dominance are *Cyprinus carpio, Labeo rohita, Ctenopharyngodon idella* and *Cirrhinus mrigala*. There is no record of fish landings available with the Department of Fisheries, Punjab in respect of Dholbaha reservoir in particular. Based on information collected from fishery contractor the monthly catch from the reservoir varies between 3.0 to 3.5 quintals, yielding in a fish yield of 57.0 kg/ha (1996-97). In addition to culturable fishes, *Barilius* spp. And *Puntius* spp. Were also observed in the reservoir. *C. carpio* ranged from 150 to 260 mm in size whereas *L. rohita* were observed from 210 to 270 mm.

Recommendations

The limnological investigations of Dholbaha reservoir exhibited medium productive status of the water body with an annual yield of 57.0 kg/ha against the productive potential of 98.0 kg/ha. The exploitation efficiency which gives the extent of utilization of net energy fixed by producers as fish is 0.58%. Though the efficiency is higher than in many other large reservoirs, it is comparable with the other small reservoir viz. Gulariya (0.61%) and Bachhra (0.58%). Fish production can be further enhanced significantly by increasing the production of IMC seed among the fish seed being stocked in the reservoir. This will help in judicious exploitation of diatoms and blue green algae in the reservoir.

The stocking policy hitherto being adopted by the Department of Fisheries, Punjab, mainly consists of release of some carp seed in the reservoir without paying adequate attention to the levels or ratios of the species based on the biogenic capacity of the ecosystem. Thus the stocking policy is dependent on availability of fish seed rather than on actual need. It is further observed that natural recruitment of major carps is either absent or poor due to non-availability of suitable breeding grounds in the lotic zone of the reservoir or on account of inadequate water inflow at the desired time of spawning. The reservoir therefore needs regular stocking of major carps. It is recommended that 270 fingerlings per hectare in the size of 100-150 mm and ratio of catla 4, rohu 3, mrigal 3 may be stocked annually. The stocking rate for the reservoir has been determined on the basis of its potential fish yield and average growth rate of the fishes as dexcribed by Jhingran (1986).

The fishing effort of the reservoir is very poor and should be enhanced with more fishermen and by providing them with nets, fishing boats as per their requirement. The Department of Fisheries may make suitable arrangement for recording of catch statistics more accurately with regards to each of the reservoir being exploited.

Operation of gill nets of mesh bar varying from 40 to 150 mm with more number of nets in 40 to 80 mm mesh bar are recommended. The depth of the nets may be adjusted according to the water level. Whenever there is complete drying of the reservoir, drag nets may be used to ensure total harvesting.

The most unfavourable features of the reservoir from a fisheries point of view is the composite auction of the reservoir alongwith two other reservoirs namely Janauri and Mali, to a single contractor. This obviously leads to improper management and exploitation. It is therefore suggested that each reservoir should be auctioned separately.

2. JANUARI RESERVOIR

2.1 Location and Mrophometry :- Januari dam project is a flood control cum irrigation project constructed at the confluence of Barootan and Sabootan tributaries of Janauri choe. The dam is located at latitude 31°-5'N and longitude 77°E. It lies 27 km away from Hoshiarpur town in the state of Punjab. Janauri dam is an earth fill dam the construction of which was taken in November 1985 under World Bank Project in Kandi tract of the district of Hoshiarpur. The initial filling of the impoundment took placed in July 1986. The water spread area of the reservoir is 18 ha at FRL. The reservoir has a total catchment area of 6.1 sq. km with a gross storage capacity of 114 ha m. It has a maximum depth of 14.0 m.The salient morphometric features are as under :-

DAM

Type	Earth fill dam
Elevation at top of dam	409.0 m
Height of dam above foundation	31.5 m
Length at top	125 m
Width at top	7 m
Width at base	165 m

Reservoir

Catchment area	6.1 km^2
Reservoir area at FRL (403.0 m)	18 ha
Gross storage capacity	114 ha m
Live storage capacity	101 ha a
Dead storage capacity	12 ha m
Normal reservoir level	403 m
Maximum reservoir level	407.25 m
Dead storage level	393.0 m
Depth at dam site	14.0 m

2.2 Meteorological and Hydrographical Observations

Janauri reservoir is mainly rainfed water body with a catchment area of 6.1 sq. m. The average annual precipitation recorded is 76.5 cm. The water level fluctuation in reservoir level is 5.375m during the year with maximum level of 402.510m and minimum level of 397.135m.

2.3 Limnology and productivity

Physico-chemical characteristics of soil:-Bottom soil of the reservoir was sandy in texture and alkaline in reaction (Table 8). Organic carbon was low, ranging from 0.38% in pre-monsoon to 0.46% in post-monsoon. Thus the organic carbon was poor than those reported from productive reservoir (0.5to 2.5%) which may be ascribed to lesser input of allochthonous organic matter into the reservoir. Available phosphorus (5.8 to 6.2 mg/100g) was above the productive mark,whereas available nitrogen (54.2 to 59.5 mg/100g) was rich in concentration.

Table: 8 Physico-chemical characteristics of soil of Janauri Reservoir.

Parameters	Pre-monsoon	Post-monsoon
Sand (%)	43.4	39.8
Silt (%)	29.5	35.4
Clay (%)	27.1	24.6
pH (%)	7.4	7.3
Organic carbon (%)	0.38	0.46
Free CO_3 (%)	0.76	0.87
Available phosphorus (mg/100g)	5.80	6.20
Available nitrogen (mg/100g)	54.2	59.5
Specific conductivity (µmhos/cm)	219.2	216.2

Physico-chemical characteristics of water:-Water temperature ranged from 13 in water to 28°c in summer and is supposed to be good for acquaculture practices. Hydrogen-ion-concentration varied from 7.4 to 7.5. The minimum values were recorded in winter while the maximum was in summer. The fluctuations in pH clearly indicates the strong buffering capacity of water. .The values of transparency were recorded in summer (78cm) while the high values in post-monsoon (105cm). High wind velocity in summer months might have resulted in low transparency. Dissolved oxygen fluctuated from 4.0 to 7.36 ppm. The maximum and minimum values were recorded in May and October. Absence of free carbon dioxide in the reservoir is another indicator of suitability of water for fish production. The seasonal variation in alkalinity was quite prominent with minimum values (166.0 ppm) in summer and maximum values (218.0 ppm) in winter months (Table 9).The total alkalinity thus was found conductive to high fish productivity.

Calcium concentration of the reservoir ranged between 22.65 and 43.28 ppm and reflected the productive nature of water body. Magnesium content was also varying from 2.91 to 11.8 ppm. Total hardness fluctuated from 112.0 to 140.0 ppm. Chloride ranged between 11.36 and 17.4 ppm. Dissolved organic matter varied between 2.4 and 7.0 ppm. High values of organic matter suggested productive state of the reservoir.

A perusal of limno-chemical species like total alkalinity (166.0-218.0 ppm),calcium (22.65-43.28.0 ppm) and specific conductivity (236.0-364.0 m mhos/cm) clearly suggest the medium productive potential of Janauri reservoir. The rich water quality reflected the transport of allochthonous dissolved nutrients and their leaching into the trophic cycling system.

Table: 9 Physico-chemical characteristics of surface water of Janauri Reservoir.

Parameters	Ranges	Average
Water temperature	13.0-28.0	22.7
Transparency	78.0-105.0	94.7
pH	7.4-7.5	7.4
Dissolved oxygen (ppm)	4.0-7.36	5.8
Free CO_2 (ppm)	Nil	Nil
Bicarbonate (ppm)	166.0-218.0	184.7
Dissolved organic matter (ppm)	2.4-7.0	4.3
Hardness (ppm)	112.0-140.0	124.0
Calcium (ppm)	25.65-43.28	35.27
Magnesium (ppm)	2.91-11.8	6.54
Chloride (ppm)	11.36-17.4	15.25
Sp. conductivity (µmhos/cm)	251.0-317.0	277.3

Thermal and chemical stratification:- Depth profile in respect of water temperature upto 10 m (Table 10) showed almost isothermal conditions in the reservoir, the temperature variation was limited to 2°C in post-monsoon months whereas it was 1°C in winter. Chemical stratification in respect of pH, dissolved oxygen, total alkalinity and specific conductivity (Table 10) was discernible.

Table: 10 Depth profile of Janauri Reservoir.

Depth	Water temp. (°C)			pH			D.O (ppm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	27.0	13.0	28.0	7.4	7.4	7.5	4.0	6.0	7.3
2	27.0	13.0	28.0	7.6	7.5	7.6	4.0	5.6	7.3
5	26.0	12.0	-	7.8	7.5	-	3.8	5.2	-
10	25.0	-	-	7.8	-	-	3.7	-	-

Depth	Free CO_2 (ppm)			Total Alkalinity (ppm)			Sp. conductivity (µmhos/cm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	Nil	Nil	Nil	170.0	218.0	166.0	251.0	264.0	317.0
2	Nil	Nil	Nil	168.0	226.0	166.0	262.0	268.0	328.0
5	Nil	Nil	-	166.0	230.0	-	262.0	268.0	-
10	Nil	Nil	Nil	166.0	-	-	265.0	-	-

Primary productivity :- The gross primary production ranged from 66.67 to 175.0 with an average of 105.6 mgC/m²/hr while the net production varied between 26.67 and 65.0 (av. 41.6) mgC/m²/hr. Based on carbon production the expected fish yield is 100 kg/ha. Respiration fluctuated from 48.0 to 132.0 mgC/m²/hr.

2.4 Biotic communities

Plankton :- The plankton population ranged from 352 u/l in winter to 410 u/l in post-monsoon (Fig.3). The annual average production of 387 u/l of plankton depicted poor population. On an average, phytoplankton formed 75.4% of total plankton. Among phytoplankters, bacillariophyceae out numbered chlorophyceae and myxophyceae both in population density as well as in species diversity. Planktonic

composition in respect of bacillariophyceae was 41.9%. The major pulse of diatoms was observed in summer (50%) whereas its minimum concentration (36.4%; Table11) was on post-monsoon months. Diatoms were comprised of the typical tropical forms viz. *Nitzschia, Diatoma, Fragilaria, Synedra, Amphora, Meridion* etc. The list of plankton is presented in Table 12) .

Chlorophyceae constituted 16.7% of total plankton and was mainly represented by *Rhizoclonium, Pediastrum, Pachycladon, Planktosphaeria* and *Troschia* . Maximum percentage of green algae was in winter (20.4%) followed by summer (20.0%). Blue green algae constituted 6.9% of the total plankton and had their dominance in summer (13.3%). *Oscillatoria* followed by *Spirulina, Cocchochlaris* and *Lyngbya* were the main components of this group. *Cystodinium* and *Peridinium* were also observed occasionally representing the group dinophyceae.

Among zooplankton, copepods (*Cyclops, Diaptomus* and nauplii) formed 12.0% of plankton followed by rotifers (*Keratella, Notholca, Brachionus, Lecane*; 7.7%), cladocerans (*Daphnia, Diaphanosoma, Moina*, 2.9%) and protozoans (*Actinosphaerium*, 2.2%).

Occurrence of pollution indicator species such as *Pediastrum* under chlorophyceae, *Caloneis, Fragilaria* under bacillariophyceae and *Oscillatoria, Spriulina, Cocchochloris* under myxophyceae were less, indicating the presence of more number of clean water indicator species in the phytoplankton community.

Table: 11 Composition of Plankton Janauri Rservoir.

Period	u/l	%of different groups			
		Chlorophyceae	Myxophyceae	Bacillariophyceae	Rotifers
Sep-Oct,96	410	15.9	20.5	36.4	4.5
Dec-Jan	352	28.5	10.8	39.2	-
May·97	400	12.5	6.2	50.0	18.7

Table:12- List of Plankton of Janauri Reservoir.

Bacillariophyceae	*- Fragilara, Meridion, Rhiocosphaenia , Amphora, Nitzshia., Frustulia, Navicula, Tabellaria, Caloneis, Achnanthes, Syndera, Diatoma.*
Chlorophyceae	*- Rhizoclonium,Troschia, Pediastrum, Pachycladon, Planktosphaeria.*
Myxophyceae	*-Spirukina, Oscillatoria, Coccholoris, Lynghya.*
Dinophyceae	*-Cystodinium, Peridinium*
Myxophceae	-Nostoc,Oscillatora
Protozoa	*-Actinosphaerium*
Roftifera	*-Keratella,Notholca, Brachionus, Lecane*
Cladocera	*-Monia, Daphina, Diaphanosoma*
Copepoda	*-Cyclops, Diaptomus, nauplii.*

Periphyton :- Periphyton population ranged between 1067 u/cm^2 in post-monsoon to 2231 u/cm^2 in summer (Fig.3 ; Table 13). On an average, it was estimated as 1552 u/cm^2. Bacillariophyceae (80.6%) dominated over chlorophyceae (9.7%) and myxophyceae (8.3%). Both qualitatively and quantitatively bacillariophyceae was the richest among the algae. It was represented by *Amphora, Fragilaria, Melosira, Nitzschia, Tabellaria, Cymbella, Caloneis, Gryosigma, Diatoma, Navicula, Achnanthes, Frustulia,*

Meridion and *Gomphonema*. Chlorophyceae was composed of *Characium* whereas myxophyceae flora were comprised of *Ocillatoria* and *Schizothrix*. *Difflugia* was the sole representative of protozoans.

Table: 13 Composition of Periphyton in Janauri Reservoir.

Period	u/cm²	% of different groups		
		Chlorophyceae	Myxophyceae	Bacillariophyceae
Sep. Oct 96	1067	9.0	9.0	82.0
Dec-Jan.	1358	7.1	7.1	85.8
May-97	2231	13.0	8.3	74.0
Average	1552	9.7	8.3	80.6

Macrobenthos :- The standing crop of bottom macrofauna was estimated as 100 u/m² in summer, 200 u/m² in post-monsoon and 100 u/m² in winter. On an average, the standing crop was estimated as 134 u/m² (Table 14). Chironomids dominated the fauna (74.6%) followed by Chaoborus larvae (25.4%). Maximum concentration of benthos were recorded in post-monsoon.

Table: 14 Composition of Benthos in Janauri Reservoir.

Species	Summer		Post-monsoon		Winter		Average	
	u/m2	gm/m2	u/m2	gm/m2	u/m2	gm/m2	u/m2	gm/m2
Chironomids	100	.26	100	0.26	100	0.26	100	0.26
Chaoborus	-.26	-	100	0.12	-	-	34	0.04
Total	100	0.26	200	0.38	100	0.26	134	0.30

Macrovegetation:- The reservoir has no aquatic vegetation in any of the season.

2.5 Stocking

Stocking of the reservoir which is being done every year as been mainly confined to the seed of mirror carp and Indian major carps. The State Fisheries Department has set up an improvised fish seed farm at Hariana town, nearly 12 km away from the reservoir. The year-wise stocking figures available are as follows:

Year	Common carp	Grass carp	IMC	Unknown spp.	Total
1990-91	1,25,000	-	-	-	1,25,000
1991-92	-	-	-	25,000	25,000
1992-93	42,000	5,000	-	-	47,000
1993-94	-	-	45.500	-	45,500
1994-95	-	-	-	-	-
1995-96	25,000	-	-	-	25,000
1996-97	25,000	-	25,000	-	50,000
Total	2,17,000	5,000	70,500	25,000	3,17,500

Taking above figures into account, the stocking rate accounted to 2530 number of fish seed per hectare per year with the dominance of *C. carpio* (68.3%). Indian major carps formed 22.2%. Continued stocking by the State Fisheries Department did not have desired impact on the fishery probably due to the small size at the time of stocking and escapement along with outflow through spillway.

Commercially fishing

The fishing for the three reservoir namely Dholbaha, Janauri and Maili was taken up by a single contractor for Rs. 38,000/-.

The Januari reservoir has no natural fishery and therefore fishes of culturable (IMC) varieties are stocked for harvesting. Fishing in the reservoir is limited to six to eight days in a month. The fishermen from Dholbaha reservoir comes to this reservoir for fishing.

On an average, the monthly catch ranges between 100 kg to 150 kg with the dominance of *C. mrigala* followed by *C. carpio, C. idella* and *L. rohita*. The annual production thus was estimated as 12.5 quintals, yielding in a fish yield of 70 kg/ha (1996-97). Submerged tree trunks and concrete building are the major obstacles for the operation of the gill nets which result in poor harvesting.

Recommendations

The limnological investigations of Janauri reservoir revealed medium productive status of the water body with an annual yield of 70 kg/ha against the productive potential of 100 kg/ha. The reservoir depicts total abundance of culturable species and absence of cat fishes. The exploitation efficiency , an index to assess the extent of utilization of net energy fixed by producers as fish is 0.70%. The higher exploitation efficiency is comparable with the observations made for small reservoirs namely Guleriya (0.61%) and Bachhra (0.58%). Fish production can be further enhanced significantly by increasing the proportion of IMC seed from the level of 22.2% of stocking so far made in the reservoir. This will help in judicious exploitation of diatoms and green algae in the reservoir.

The stocking policy hitherto being adopted by the Deptt. of Fisheries, Punjab is dependent on the availability of fish seed rather than on actual need. Natural recruitment of major carps is either absent or poor due to non-availability of suitable breeding grounds in lotic zone of the reservoir. The reservoir hence need stocking support. It is recommended that 280 fingerlings per hectare in the size of 100-150 mm and ratio of catla 4, rohu 3, mrigal 3, may be stocked annually. The stocking rate has been determined as described by Jhingran (1986).

The fishing efforts of the reservoir is very poor and need enhancement with more number of fishing days and with more fishermen by providing them nets, fishing boats as per their requirement. Suitable arrangements for recording of catch statistics by the Deptt. of Fisheries, Punjab are also required. Operation of gill-nets ranging from 40 to 150 mm mesh bar are recommended. The drag-nets may be used for total harvesting whenever there is complete drying of the reservoir. The composite auction of the reservoir alongwith two other reservoirs to a single contractor is also an unfavourable feature from a fisheries point of view. This obviously leads to improper management and exploitation. Hence, each reservoir should be auctioned separately.

3. Maili Reservoir

3.1 Location & morphometry:- Maili dam is an earth fill dam 23.3m high from river bed and was constructed on Maili choe in Hoshiarpur district in the state of Punjab, for irrigation and flood control . This is one of the project aided by the World Bank under Kandi Watershed and Area Development Programme. The dam has a base width of 117 m and top width of 6 m. An outlet under the dam has been constructed to utilze the water stored in the reservoir for irrigation. A concrete spillway has been constructed on the right side of the dam to pass water in excess of the capacity of the reservoir. The Maili reservoir has a total water spread area of 46.4 ha at FRL. It has a catchment area of 17 Km^2 with a gross capacity of 283 ha m. Downstream of the dam there is a net work of irrigation distribution system. It consists of 0.83 Km long underground carrier channel to take water from outlet works of the dam into two open distributaries. The salient morphometric features of dam and reservoir are as under:-

DAM

Type	:	Earth fill dam
Elevation at the top of dam	:	378.75 m
Height of dam above choe bed	:	23.5 m
Length at top	:	334.0m
Width at top	:	6.0m
Maximum width at base	:	117.0m

RESERVOIR

Area at FRL (373.0 m)	:	46.4 ha
Catchment area	:	17.0 km^2
Gross storage capacity	:	283.0 ha m
Live storage capacity	:	18.0 ha m
Normal full reservoir level	:	373.0 m
Maximum reservoir level	:	376.75 m
Dead storage level	:	364.0 m
Depth at dam site	:	11.0 m
Flood discharge	:	300.0 cusecs

3.2 Meteorological and Hydrographical observations :- The average annual precipitation recorded is 153.9 cm. The water fluctuation in the reservoir, was 5.66 m.

3.3 Limnology and productivity

Physico-chemical characteristics of soil :- The bottom soil was sandy in texture (56.4 to 61.6%)and was alkaline in reaction (pH 7.4-7.5). The increase in percentage of sand from 56.4 to 61.6 during post-monsoon (Table 15)may be due to influx of rain water loaded with more sand from the catchment area. The overall high percentage of sand revealed poor water retention capacity of soil. Organic carbon (0.23-0.27%) and available phosphorus (4.8-5.2 mg/100g) exhibited poor quality of soil.

Table: 15 Physico-chemical characteristics of soil of Maili Reservoir.

Parameters	Pre-monsoon	Post-monsoon
Sand (%)	56.4	61.6
Silt (%)	28.2	26.5
Clay (%)	15.4	11.9
pH (%)	7.5	7.4
Organic carbon (%)	0.27	0.23
Free CO_3 (%)	1.06	1.14
Available phosphorus (mg/100g)	4.8	5.2
Available nitrogen (mg/100g)	43.9	46.9
Specific conductivity (µmhos/cm)	161.3	216.2

Physico-chemical characteristics of water :- The water temperature fluctuated from a minimum of 13.0°c in winter to a maximum 29.0°c in summer months (Table 16). The narrow range of fluctuation in hydrogen-ion-concentration from 6.7 in winter to 7.7 in post-monsoon exhibited a strong buffering capacity of the reservoir which did not allow pH to change much. Transparency ranged between 47.0 and 139.0 cm. The low values recorded in summer months might be due to winds of high velocity. The high values observed in winter were probably due to low wind action. Dissolved oxygen varied from 4.4 and 7.0 ppm. Free carbon dioxide was completely absent in the reservoir which indicate the suitability of water for fish culture. The seasonal variations in alkalinity was quite discernible (Table 16) with minimum value of 150.0 ppm in summer and 180.0 ppm in post-monsoon. The alkalinity values also indicated conduciveness of water body for higher fish productivity.

The productive nature of reservoir was also evident with the high values of calcium concentration varying between 16.0 and 32.0 ppm. Magnesium content was also of high order, ranging between 2.9 to 10.8 ppm. Values of total hardness varied from 52.0 to 104.0 ppm (Table 16). Chloride concentration fluctuated between 17.0 and 22.7 ppm. Dissolved organic matter is an important parameter reflecting the productive nature of water. It ranged from 1.0 to 8.0 ppm. Organic matter having value of more than 1.0 ppm is considered to be indicative of high production potential. The productive state of the reservoir was evident from the higher values of specific conductivity varying from 222.0 in winter to 312.0 µmhos/cm in summer.

The delineation of foregoing hydrological parameters clearly reflects the high productivity potential of Maili reservoir. The rich water quality showed the transport of allochthonous dissolved nutrients and their leaching into the trophic cycling system.

Table: 16 Physico-chemical characteristics of surface water of Maili Reservoir.

Parameters	Ranges	Average
Water temperature	13.0-28.0	22.7
Transparency	78.0-105.0	94.7
pH	7.4-7.5	7.4
Dissolved oxygen (ppm)	4.0-7.36	5.8
Free CO_2 (ppm)	Nil	Nil
Bicarbonate (ppm)	166.0-218.0	184.7
Dissolved organic matter (ppm)	2.4-7.0	4.3
Hardness (ppm)	112.0-140.0	124.0
Calcium (ppm)	25.65-43.28	35.27
Magnesium (ppm)	2.91-11.8	6.54
Chloride (ppm)	11.36-17.4.	15.25
Sp. conductivity (µmhos/cm)	251.0-317.0	277.3

Thermal and chemical stratification :- Depth profile observations carried during winter showed nearly isothermal condition in the reservoir (Table 17). The water temperature fluctuated from 13.0°C at surface to 12.0°C at 4 m depth and was constant upto 8 m depth. pH varied from 6.7 at surface to 7.3 at 8 m depth while total alkalinity fluctuated from 180.0 at surface to 192.0 ppm at 8 m depth. Specific conductivity ranged between 222.0 (surface) and 232.0 µmhos/cm (8 m). The variations in respect of total alkalinity and specific conductivity exhibited presence of weak chemical stratification in the reservoir.

Table: 17 Depth profile of Maili Reservoir.

Depth	Water temp. (°C)			pH			D.O (ppm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	27.0	13.0	29.0	7.7	6.7	7.2	5.12	4.4	7.0
2	-	13.0	-	-	6.8	-		4.0	-
4	-	12.0	-	-	7.1	-		4.0	-
6	-	12.0	-	-	7.2	-		4.0	-
8	-	12.0	-	-	7.3	-		4.0	-

Depth	Free CO_2 (ppm)			Total Alkalinity (ppm)			Sp. conductivity (µmhos/cm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	Nil	Nil	Nil	196.0	180.0	150.0	235.0	222.0	312.0
2	-	Nil	-	-	180.0	-	-	227.0	-
4	-	Nil	-	-	180.0	-	-	228.0	-
6	-	Nil	-	-	192.0	-	-	228.0	-
8	-	Nil	-	-	192.0	-	-	232.0	-

Primary productivity :- The gross primary production ranged from 53.3 to 115.0 mgC/m²/hr while the net production varied between 26.7 and 58.3 mgC/m²/hr . The average respiration was 49.5 mgC/m²/h . The expected fish yield in terms of carbon production was estimated as 79 kg/ha. The ratio of net and gross carbon production was found to be 0.65.

3.4 Biotic communities

Plankton :- The annual average production of 319 u/l of plankton (Table18) depicted poor plankton population in the reservoir. It ranged from 275 u/l in post-monsoon to 400 u/l in summer (Fig.3). Phytoplankton constituted 72.6% of the total plankton. The qualitative description of the plankton is depicted in Table 19.

Bcillariophyceae was the most dominant group both qualitatively and quantitatively among phytoplankters and on an average it formed 58.1% of the total plankton population. The pulse of diatoms was observed during winter (53.7%). The common forms encountered *were Melosira, Diatoma, Caloneis, Navicula, Pinnularia, Tabellaria, Synedra, Eunotia* and *Gyrosigma.* Chlorophyceae was next in order of preponderance and formed 28.0% of the plankton population and was mainly represented by *Rhizoclonium, Pediastrum, Pchycladon* and *Troschia*. Myxophyceae accounted 5.4% of the total plankton and fluctuated from 6.2 in summer to 10.0% in post-monsoon. *Oscillatoria* and *Microcystis* were the dominant forms observed. Zooplankton were mainly dominated by copepods (*Cyclops, Diaptomus* and nauplii) forming 14.7% of the plankton. Cladocerans (*Daphnia*) constituted 10.4% while rotifers formed 2.1% of the plankton.

Occurrence of pollution indicator species like *Pediastrum* under chlorophyceae; *Cymbella, Stauroneis, Caloneis* under bacillariophyceae and *Oscillatoria, Nostoc* under myxophyceae were rare which indicates the dominance of clean water species in the phytoplankton community.

Table: 18 Composition of Plankton Maili Rservoir.

Period	u/l	%of different groups			
		Chlorophyceae	Myxophyceae	Bacillariophyceae	Rotifers
Sep-Oct,96	275	36.7	10.0	20.0	-
Dec-Jan	283	29.3	-	53.7	-
May-97	400	18.0	6.2	43.8	6.2
Average	319	28.0	5.4	59.2	2.1

Table:19- List of Plankton of Janauri Reservoir.

Bacillariophyceae	*-Cyclotella, Navicula, Diatoma, Meridion, Tabellario, Pinnularia., Stauroneis, Cymbella, Caloneis.*
Chlorophyceae	*- Pachycladon, Rhizoclonium, Scenedesmus, Troschia*
Myxophyceae	*-Oscillatoria, Microcystis, Nostoc*
Dinophyceae	*-Cystodinium, Peridinium*
Myxophceae	*-Nostoc,Oscillatora*
Rotifera	*-Brachinous, Notholca*
Cladocera	*-Daphnia, Diaphanosoma*
Copepoda	*-Daiptomus, Cyclops, nauplii*

Periphyton :- On an average periphyton population was 1455 u/cm^2. It ranged from 1164 u/cm^2 in post-monsoon to 1746 u/cm^2 in summer (Table 20 ; Fig. 3).Bacillariophyceae was the richest (80.4%) both quantitatively and qualitatively. It was represented by *Fragilaria, Cymbella, Caloneis, Diatoma, Nitzschia, Syndra, Navicula, Achnanthes, Eucocconeis, Tabellaria, Frustulia, Cocconeis, Gyrosigma* and *Neidium.* Chlorophyceae (10.5%) was comprised of *Characium* and *Cosmarium* while myxophyceae (9.1%) were consisted of *Schizothrix* and *Oscillatoria*.

Table: 20 Composition of Periphyton in Maili Reservoir.

Period	u/cm^2	% of different groups		
		Chlorophyceae	Myxophyceae	Bacillariophyceae
Sep. Oct 96	1164	8.3	8.3	83.4
Dec-Jan.	1455	6.6	13.4	80.0
May-97	1746	16.7	5.5	77.8
Average	1455	10.5	9.1	80.4

Macrobenthos :- Due to rocky bottom of the reservoir, the collection and studies of macrobenthos were not possible.

Macrovegetation :- The reservoir is devoid of any marginal, submerged, emergent of free floating macrophytes.

3.5 Stocking

Continued stocking by the Department of Fisheries, Punjab has been reported. The year-wise stocking figures available are as follows :-

Year	Common carp	Grass carp	IMC	Unknown spp.	Total
1990-91	1,60,000	-	-	-	1,60,000
1991-92	-	-	-	50,000	50,000
1992-93	26,000	6,000	-	-	32.000
1993-94	-	-	-	-	-
1994-95	-	-	-	-	-
1995-96	25,000	-	-	-	25.000
1996-97	25,000	-	25,000	-	50.000

On an average a total of 45,285 fish seed have been stocked in the reservoir every year. The rate of stocking is therefore 964 ha/yr dominated by C. carpio (74.5%) followed by IMC (7.9%). The stocking of the reservoir at this high rate, however, did not have desired impact on the fishery probably due to the small size at the time of stocking and also due to escapement along with outflow through spillway.

3.6 Commercial fishing

Maili reservoir along with two other reservoirs namely Dholbaha and Janauri were auctioned for a sum of Rs. 38,000/- to a single contractor. The fishing in the reservoir is conducted for only two days in a month by the fishing parties of Dholbaha reservoir. First July to 31st August is observed as close season for fishing. The monthly catch is reported to range from 40 to 50 Kg with the dominance of *C. mrigla, C. carpio, L. calbasu, C.idella* and *L. rohita*. There is no record of fish landings available with the Department of Fisheries,Punjab in respect of Maili reservoir. The estimated annual fish production was 5.0 quintals, yielding in a fish yield of 10.0 Kg/ha (1996-97). In addition to culturable fishes, *Barilius spp*. And *Puntius spp*.were also observed. The reservoir thus has no natural fishery. No breeding of fishes in the upper reaches has so far been noticed. Escapement of fish through spillway reported.

3.7 Recommendations

The delineation of limnological parameters of Maili reservoir exhibited medium productive status of the ecosystem with an annual yield of 10 kg/ha. The reservoir has shown total dominance of culurable species of Indian major carps and the absence of cat fishes. The exploitation efficiency is 0.15%. The low exploitation is due to improper management and exploitation of the reservoir. Fish production can be enhanced significantly by following a judicious exploitation-cum-stocking policy. The increase in the stocking of IMC seed from the level of 7.9% of stocking so far made in the reservoir will help in judicious exploitation of diatoms and the green algae in the ecosystem. The stocking by the Department of Fisheries, Punjab is dependent on the availability of the fish seed rather than on actual need. Natural recruitment of major carps in the reservoir is either absent or poor due to non-availability of suitable breeding grounds. The reservoir hence need stocking support.

It is suggested that 240 fingerlings per hectare in the size range of 100-150 mm and ratio of catla 4, rohu 3, mrigal 3 , may be stocked annually.

The fishing effort limited to two days of fishing in a month is poor and needs enhancement with more number of fishing days and with more number of fishermen by providing them nets, fishing boats as per

their requirement. Operation of gill-nets ranging from 40 to 140 mm mesh bar are recommended. Suitable arrangements for recording of catch statistics by the Department of Fisheries, Punjab, are suggested. The composite auction of the reservoir along other reservoirs to a single contractor is also an unfavourable feature from a fisheries point of view. This obviously leads to improper management and exploitation. Hence, each reservoir should be auctioned separately.

4. NANGAL RESERVOIR

4.1 Location and Morphometry:-Nangal lake covering a water spread area of 280 ha, is situated about 13 Km downstream of the Bhakra dam on river Sutlej at Nangal in the district of Roopnagar, Punjab.

Nangal dam has 26 bays of 9.14m length each. It is founded on conglomerate and is 29 m high from the deepest foundation level to the breast wall. The length of the dam is 304.8 m. It is designed to pass a flood discharge of 9910 cumecs. The dam diverts the water of river Sutlej into the Nangal channel for power generation and irrigation purposes. The Nangal reservoir acts as a balancing reservoir to smoothen out the diurnal variation in releases from the Bhakra power plants. The Nangal hydel channel is 64.5 Km long and is a lined channel. The natural falls along the channel are utilised for generating power.

4.2 Meteorological and Hydrographical observations:- The annual precipitation was 133.4 cm. The reservoir water level had a fluctuation of 2.14 m from a maximum level of 351.72m to a minimum level of 349.58m.

4.3 Limnology and productivity

Physico-chemical characteristics of soil:- The bottom soil of the reservoir was highly sandy in texture (65.3 to 73.3%), reflecting poor water retention capacity of soil. Acidic state of soil was evident by pH value of 6.5 to 6.8 (Table 21). The soil was however rich in organic carbon (1.08 to 1.23%), available phosphorus (7.6 ro8.2 mg/100g) and available nitrogen (72.9 to 76.8 mg/100g).

Table: 21 Physico-chemical characteristics of soil of Nangal Reservoir.

Parameters	Pre-monsoon	Post-monsoon
Sand (%)	73.2	65.3
Silt (%)	13.4	15.6
Clay (%)	13.2	19.0
pH (%)	6.8	6.5
Organic carbon (%)	1.08	1.23
Free CO_3 (%)	0.52	0.63
Available phosphorus (mg/100g)	8.2	7.6
Available nitrogen (mg/100g)	72.0	76.8
Specific conductivity (µmhos/cm)	284.2	304.3

Physico-chemical characteristics of water:- The water temperature ranged from a minimum of 15.5 °C in winter to maximum of 21.0°C in summer months indicating cold water condition. The average water temperature was 18.8°C (Table 22). The hydrogen-ion-concentration fluctuated from 7.2 in summer to

7.9 in winter. The narrow variation in the pH exhibited a strong buffering capacity of the reservoir which did not allow pH to change much. Transparency varied between 26.0 and 87.0 cm. The low values recorded in summer months might be due to winds of high velocity. The high values were observed in winter. Dissolved oxygen fluctuated from 6.4 to 7.2 ppm. Free carbon dioxide was completely absent in winter and post-monsoon months and appeared in summer months at a concentration of 32.0 ppm. Thus the seasonal variations was quite discernible. The total alkalinity varied from 72.0 in post-monsoon to 80.0 ppm in winter. These medium values of alkalinity showed medium productive state of water body.

Calcium concentration of the reservoir varied from 22.4 to 38.4 ppm and reflected the productive nature of water body. Magnesium content was also high varying between 5.88 to 7.88 ppm. Total hardness fluctuated from 88.0 to 120.0 ppm. Chloride values remained static at 14.2 ppm. Dissolved organic matter varied from 0.6 to 6.4 ppm suggesting productive state of the reservoir.

Table: 22 Physico-chemical characteristics of surface water of Nangal Reservoir.

Parameters	Ranges	Average
Water temperature	15.5-21.0	18.8
Transparency	16.0-87.0	57.0
pH	7.2-7.9	7.5
Dissolved oxygen (ppm)	6.4-7.2	6.67
Free CO_2 (ppm)	Nil-32.0	10.7
Bicarbonate (ppm)	72.0-80.0	76.7
Dissolved organic matter (ppm)	0.6-6.4	2.7
Hardness (ppm)	88.0-120.0	98.7
Calcium (ppm)	22.0-38.4	28.2
Magnesium (ppm)	5.8-7.8	6.8
Chloride (ppm)	14.2	14.2
Sp. conductivity (mmhos/cm)	138.0-199.0	164.3

Thermal and chemical stratification :- Depth profile observations made upto a maximum depth of 4 m indicated isothermal conditions with respect to temperature (Table 23). Weak chemical stratification in respect of total alkalinity and specific conductivity was discernible.

Table: 23 Depth profile of Nangal Reservoir.

Depth	Water temp. (°C)			pH			D.O (ppm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	20.0	15.5	21.0	7.4	7.9	7.2	6.4	7.2	6.7
2	20.0	15.5	21.0	7.3	7.7	7.1	6.3	6.8	6.5
4	20.0	15.5	-	7.2	7.6	-	6.3	6.4	-

Depth	Free CO_2 (ppm)			Total Alkalinity (ppm)			Sp. conductivity (µmhos/cm)		
(m)	Post-mon	Winter	Summer	Post-mon	Winter	Summer	Post mon	Winter	Summer
S	Nil	Nil	32.0	72.0	80.0	78.0	138.0	156.0	199.0
2	Nil	Nil	24.0	62.0	82.0	78.0	139.0	161.0	199.0
4	Nil	Nil	-	62.0	84.0	-	140.0	162.0	-

Primary productivity :- The gross primary production ranged from 60.6 in post-monsoon to 133.3 mgC/m²/hr in winter months while the net production varied between 26.7 and 65.0 mgC/m²/hr. The expected fish yield in terms of carbon production is 57 kg/ha.

4.4 Biotic communities

Plankton :- The plankton population fluctuated from 283 u/l in summer to 372 u/l in winter months (Fig. 4). The annual average production of 336 u/l of plankton depicted poor population in the reservoir. On an average, phytoplankton constituted 87.6% of the total plankton. Among phytoplankters, bacillariophyceae out numbered chlorophyceae and myxophyceae both in population densities as well as in species diversity. Planktonic composition in respect of bacillariophyceae was 40.7%. The major pulse of diatoms was observed in summer (45.8%) while its minimum concentration (33.3%; Table 24) was in post-monsoon months. Diatoms were commonly by *Tabellaria, Fragilaria, Cymbella, Caloneis, Meridion, Diatoma* and *Navicula*. The list of plankton observed is presented in Table 25.

Chlorophyceae formed 19.4% of the total planktonic population and was mainly represented by *Rhizoclonium, Planktosphaeria, Botrycoccus, Nitella* and *Scenedesmus*. Maximum concentration of green algae was recorded in winter (26.2%) whereas the minimum percentage was in post-monsoon. Blue green algae constituted 17.2% of the total plankton and were represented by *Merismopedia, Nostoc, Phormidium* and Oscillatoria. Dinophyceae (*Cystodinium, Peridinium, Ceratium*) formed 10.3% of the plankton. Among zooplankton, copepods (Cyclops) formed 4.2% of plankton. Rotifers (*Brachionus*) constituted 3.7% while cladocerans (*Bosmina*) represented 2.8% of the total plankton.

Table: 24 Composition of Plankton Nangal Rservoir.

Period	u/l	%of different groups			
		Chlorophyceae	Myxophyceae	Bacillariophyceae	Rotifers
Sep-Oct,96	353	11.1	19.5	33.3	11.0
Dec-Jan	372	26.2	23.8	42.9	-
May·97	283	20.8	8.3	45.8	-
Average	336	19.4	17.2	40.7	3.7

Table:25- List of Plankton of Nangal Reservoir.

Bacillariophyceae	*-Diatoma, Navicula, Cyclotella, Cocconeis, Frustulia, Meridion, Melosira, Cymbella*
Chlorophyceae	*-Characium, Scenedesmus, Botryococcus, Planktosphaeria , Nitella, Rhizoclonium, Cosmarium, Ulothrix.*
Myxophyceae	*-Merismopedia, Microcystis, Oscillatoria, Phormidium, Nostoc*
Dinophyceae	*- Peridinium, Cystodinium, Ceratium.*
Protozoa	*-Arcella*
Rotifera	*-Brachionus*
Cladocera	*-Bosmina*
Coepoda	*-Cyclops*

Periphyton :- Periphytic communities, both quantitatively and qualitatively dominated by bacillariophyceae. It ranged between 776 u/cm² in post –monsoon and 1261 u/cm² in summer months (Fig.4). On an average the annual standing crop was 1002 u/cm² (Table 26). Diatoms were represented by *Navicula, Diatoma, Cymbella, Nitzschia, Caloneis, Eucconeis, Tabellaria, Neidium, Gomphonema, Gyrosigma* and *Frustulia*. Chlorophyceae was comprised of *Characium* whereas myxophyceae flora were comprised of *Lyngbya* and *Schizothrix*.

Table: 26 Composition of Periphyton in Nangal Reservoir.

Period	u/cm²	% of different groups		
		Chlorophyceae	Myxophyceae	Bacillariophyceae
Sep. Oct 96	776	12.5	-	87.5
Dec-Jan.	970	10.0	10.0	80.0
May 97	1261	7.7	23.1	69.2
Average	1002	10.0	11.0	78.9

Macrobenthos :- The annual standing crop of bottom macro fauna of 300 u/m² was recorded in post-monsoon months. Chironomids formed 66.6% of total benthos followed by *Chaoborus* 33.4% (Table 27). Continuous under water current in the lake might have resulted in the poor standing crop.

Table: 27 Composition of Benthos in Nangal Reservoir.

Species	Summer		Post-monsoon		Winter		Average	
	u/m²	mg/m²	u/m²	mg/m²	u/m²	mg/m²	u/m²	mg/m²
Chironomids	-	-	200	0.52	-	-	200	0.52
Chaoborus	-	-	100	0.12	-	-	100	0.12
Total	-	-	300	0.64	-	-	300	0.64

Macrovegetation :- Macrovegetation in Nangal reservoir ranged from 300 g in summer to 1500 g in post-monsoon per sq. m. wet wt. Showing an average 750 g/m²/month wet wt. (Table 28). *Hydrilla, Potamogeton, Vallisneria , Nelumbo, Marsilea* and *Thypa* were the common forms encountered. The marginal areas had profuse growth of macrophytes.

Table : 28 Composition of Macrovegetation in Nangal Reservoir.

Season	Wet wt (g/m2)	Dry wt. (g/m2)
Summer	300	50
Post-monsoon	1500	50
Winter	750	20
Average	750	50

4.5 Biology of fishes

Length-weight relationship :- The length-weight relationship of the following species of fish from the reservoir were estimated.

i) *Tor putitora* -Log $W=1.9539 \log^{L-2.4701}$

$W=3.3876 \times 10^{-3L.19539}$

ii) *S. plagiostomus* -Log $W=2.6838 \log^{L-4.2433}$

$W=5.7228 \times 10^{-5L-2.6838}$

iii) *C. carpio* -Log $W=1.3009 \log^{L-0.7277}$

$W=0.1871^{L-1.3009}$

4.6 Food and feeding habits :- Observations on the food of *C. carpio* showed its omnivorus nature with dominance of decayed organic matter (67%) in the food content. Other food items were bacillariophyceae (15%), sand and mud (12%) and chlorophyceae (6%). *Schizothrax plagiostomus* is mainly a bottom feeder fish depending upon bottom organisms (50%), detritus (15%), chlorophyceae (10%), higher plant matter (20%), mud and sand (5%). Food of *L. rohita*-was composed of 45.5% algae matter, 2.5% chlorophyceae, 26% mud and silt.

4.7 Stocking

A total of 1.5 lakh of fish seed @1500/ha were stocked in 1995-96 by the State Fisheries Department, Punjab.

4.8 Commercial fishing

The State Fisheries Department has been auctioning the reservoir and the revenue earned by auction increased steadily from Rs. 62,200 in the year 1988-89 to Rs. 1,41,000 (1993-94) and thereafter declined to Rs. 97,000 (1994-95). The auction amount for the year 1996-97 was Rs. 1,16,000. The fishing in the reservoir is m mostly done by the fishing parties brought from the other states by the contractors. There is no exclusive fishermen village on the periphery of the reservoir. The commercial nets are in the form of small gill-net designed to suit the operation in the areas having low depth and infested with the weeds. These net are locally called patties having mesh bar ranging from 30 to 120 mm.

Although no record of fish landings was available at the local office of Fisheries Department, data obtained from fish contractor revealed an estimated landings of 3.3 t in 1992-93 followed by 4.0 t in 1993-94, 4.2 t in 1994-95 and 3.5 t in 1995-96. The fish catch during 1996 was 3.8 t of which 13.75% catch was in the month of May and 1.65% in July. Almost 50% of annual catch was during pre-monsoon period. The fish catch was dominated by *C. carpio* by number (69.0%) followed by *S. plagiostomus* (14.41%), *L. dero*, *L. bata* (9.95%) and *T. putitora* (6.63%). *C. garua* appeared in negligible quantity. *H. molitrix* has also been reported from the reservoir.

4.9 Recommendations

Soil of the reservoir was fertile due to high organic matter owing to decaying of submerged aquatic weeds. Thus the energy brought in was through the allochthonous as well as autochthonous sources. Limno-chemical species like total alkalinity (72.0-80.0 ppm), calcium (22.0-38.4 ppm) and specific conductivity (138.0-223.0 µmhos/cm) indicated medium productive state of the water body. This was further substantiated by the productive potential of 57.0 kg/ha. The cold water regime of the reservoir favoured the growth of cold water species like *C. carpio, S. palgiostomus, L. dero* and *T. putitora* with an annual yield of 13.5 kg/ha. The energy transformation from producers to fish was worked out to be 0.24%. The main flow of energy was through detritus food chain.

Natural recruitment of major carp is either absent or very poor due to unfavourable water temperature range of 15-21°C prevailing in the reservoir. Stocking of reservoir by Deptt. of Fisheries, Punjab, is totally based on the availability of seed rather than on actual need. Taking an annual growth rate of 0.5 kg for each of the species of carps stocked and giving an allowance of 50% loss, the stocking rate will be 170/ha. In addition to framing of judicious stocking policy, it will also be appropriate to make some step for conservation of fisheries of snow trout, *S. palgiostomus* and *T. putitora* in Nangal lake.

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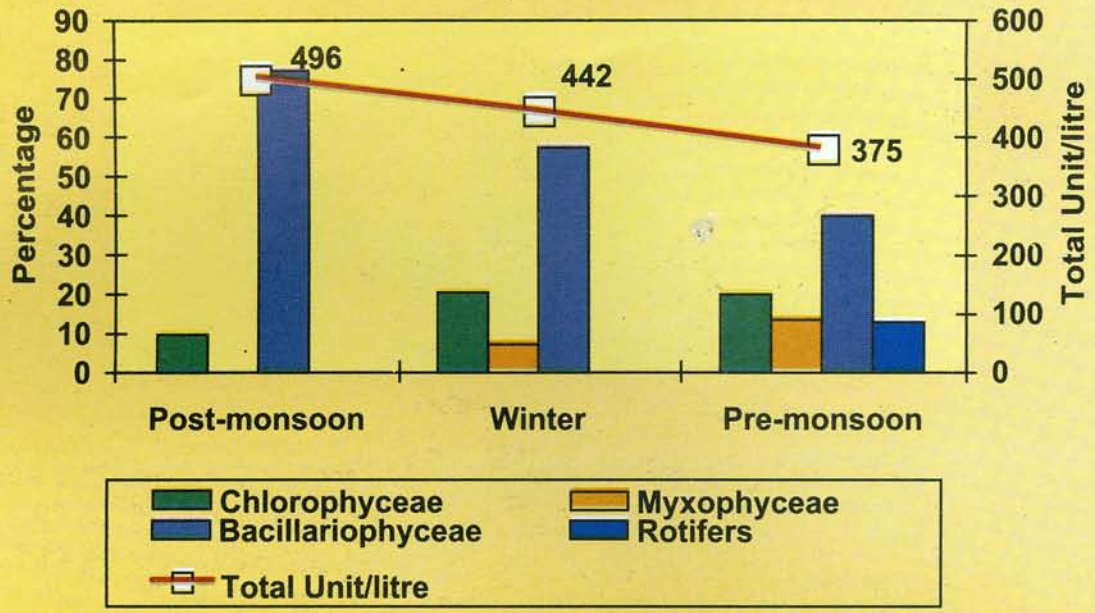
Fig. 2 - Composition of Plankton in Dholbaha Reservoir.



Composition of Periphyton in Dholbaha Reservoir.

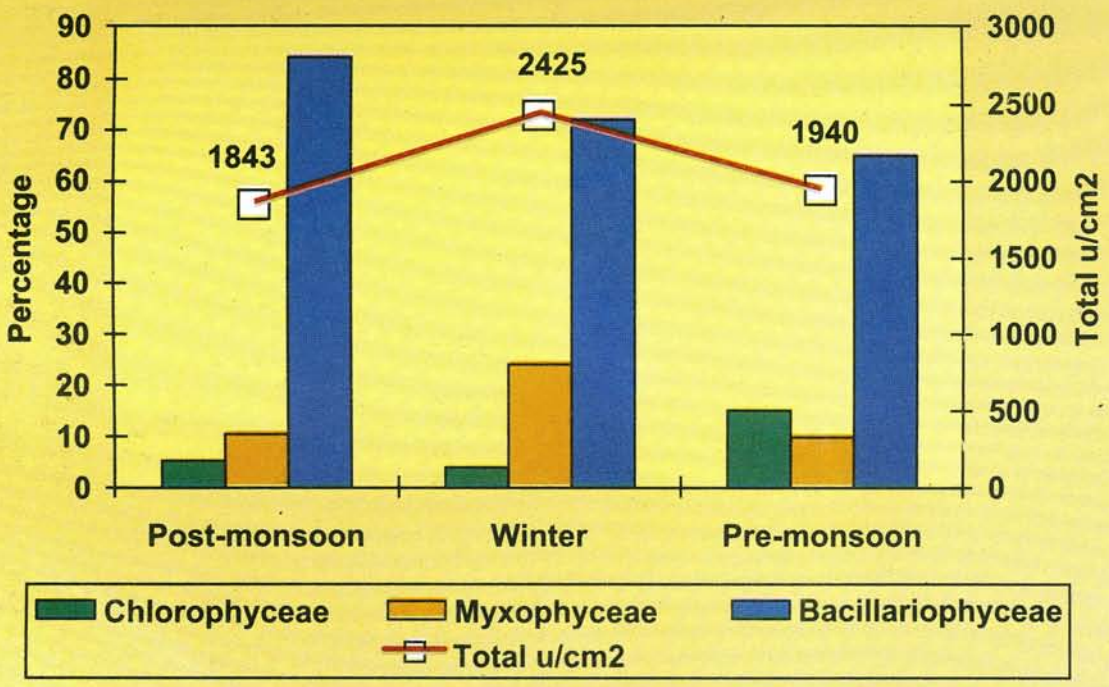
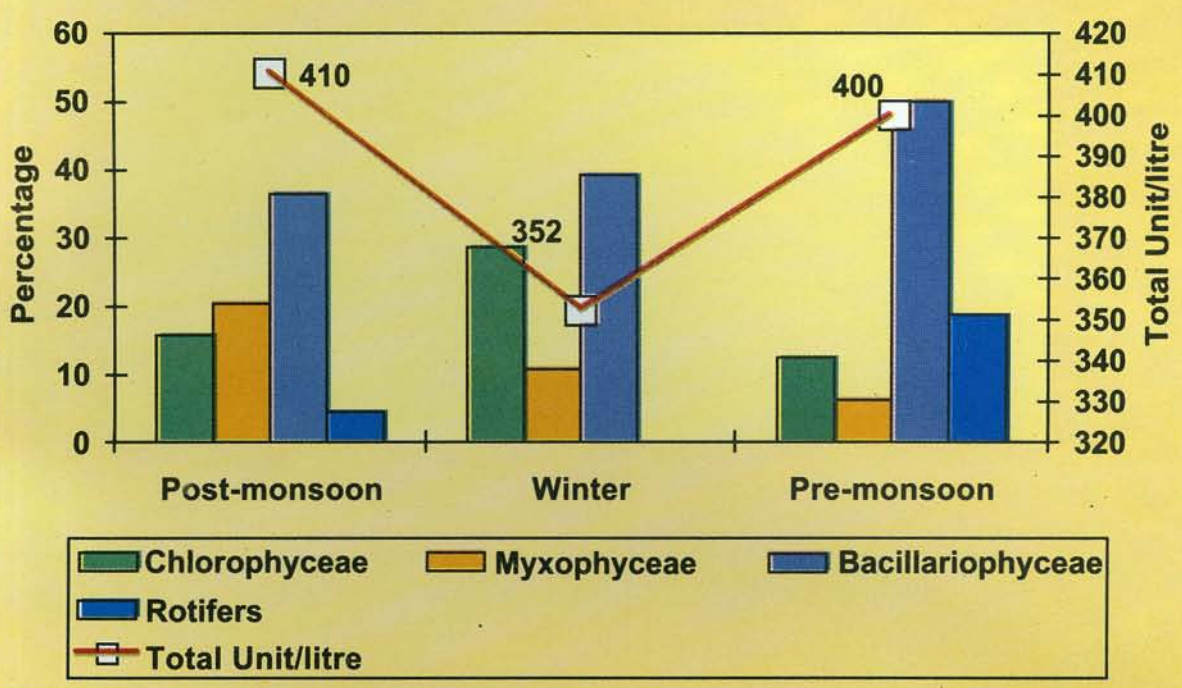


Fig. 3 - Composition of Plankton in Janauri Reservoir.



Composition of Periphyton in Janauri Reservoir.

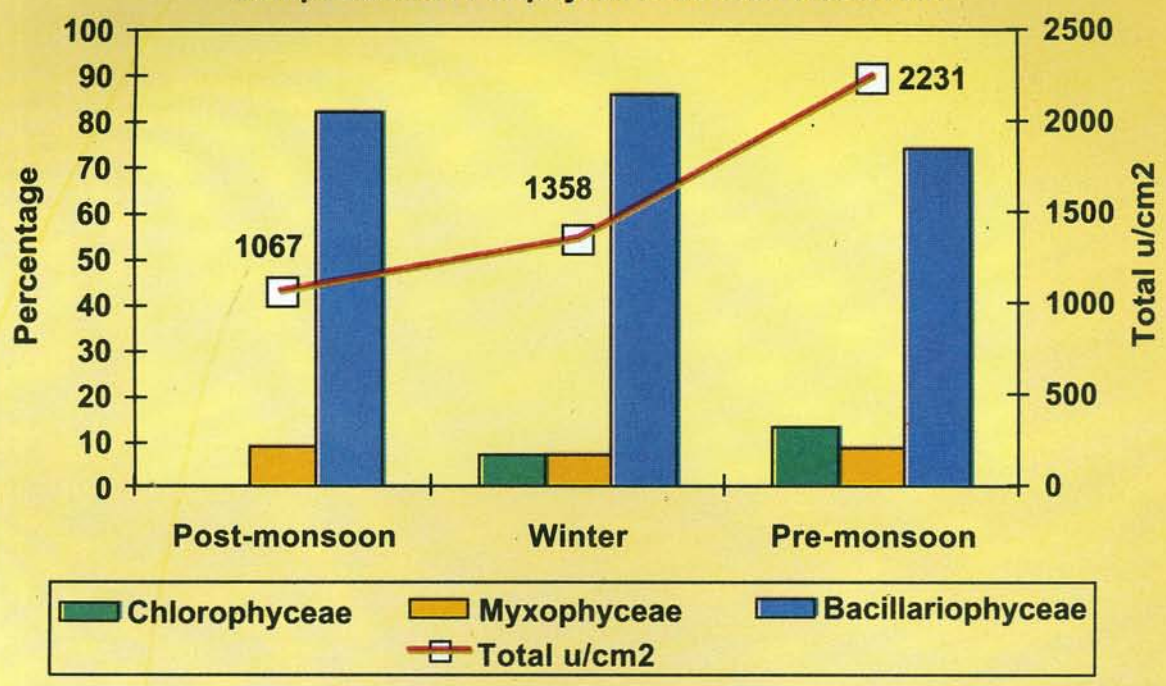
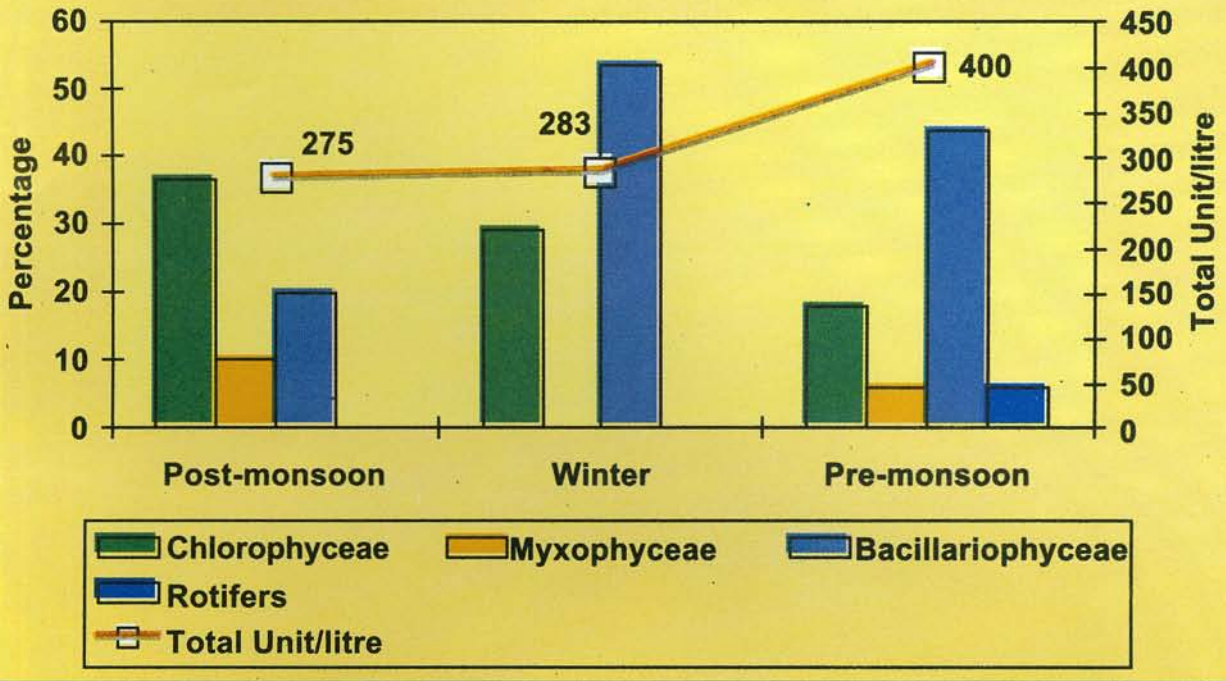


Fig.4- Composition of Plankton in Maili Reservoir.



Composition of Periphyton in Maili Reservoir.

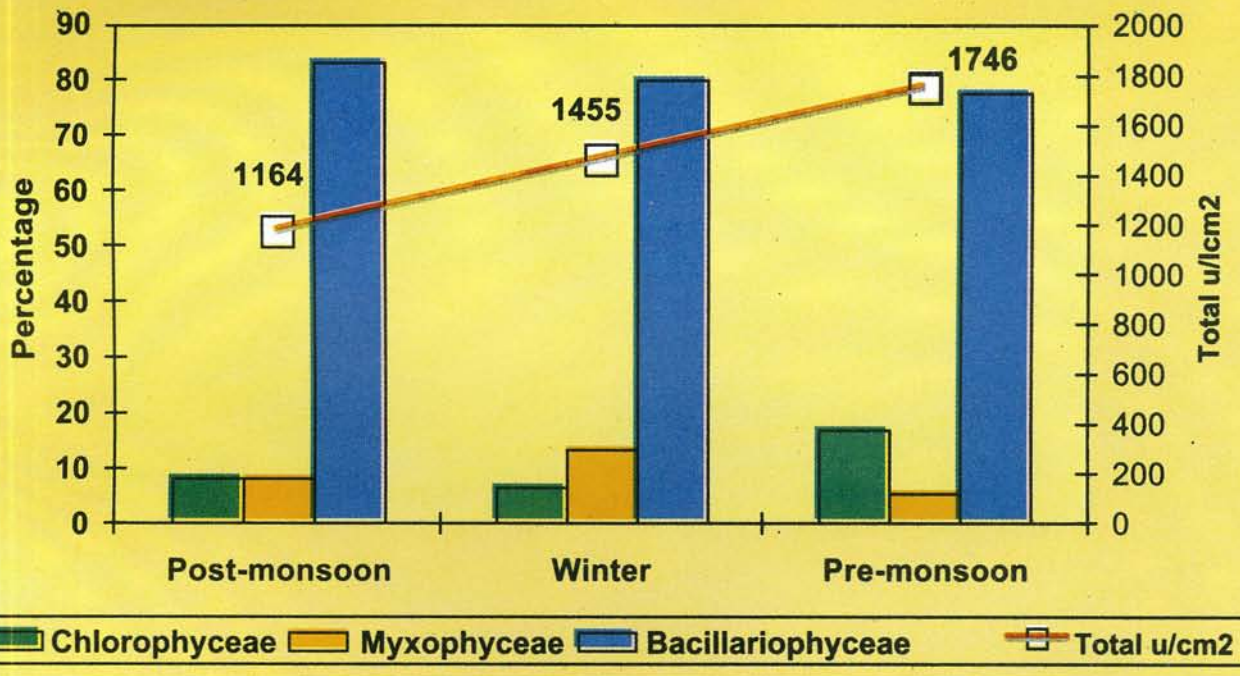
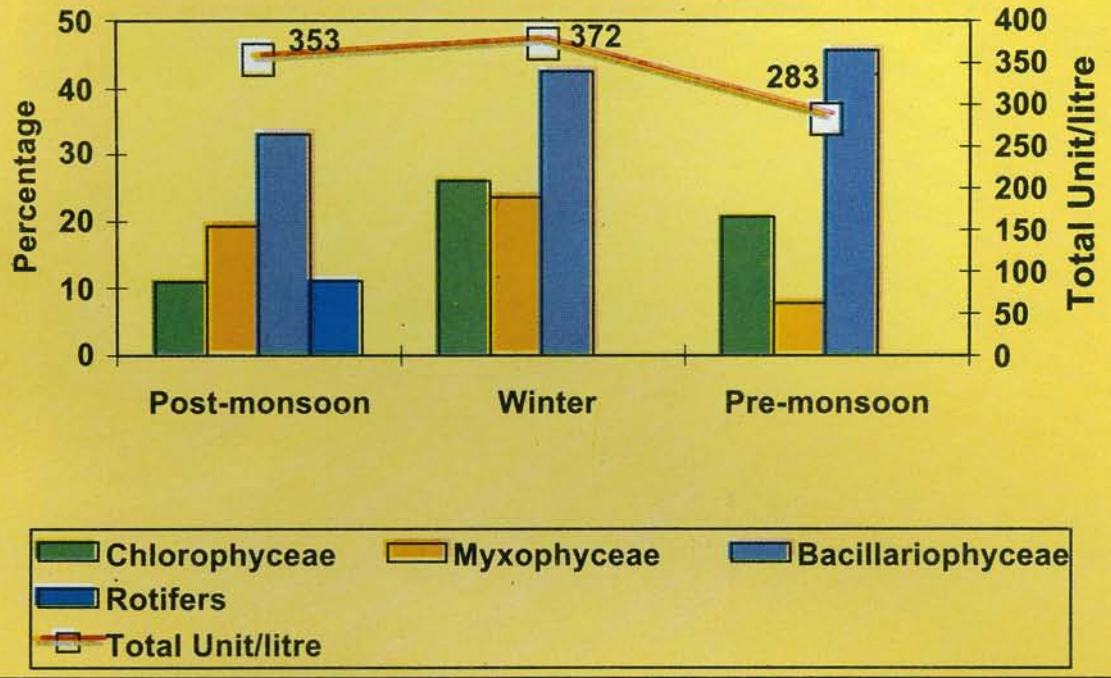
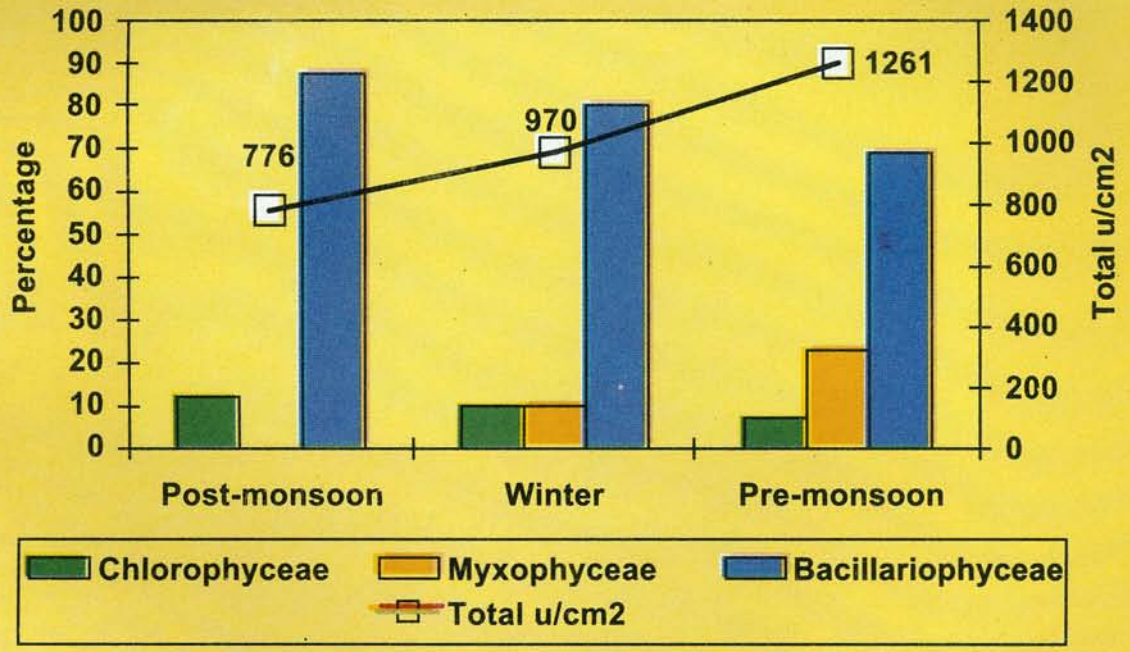


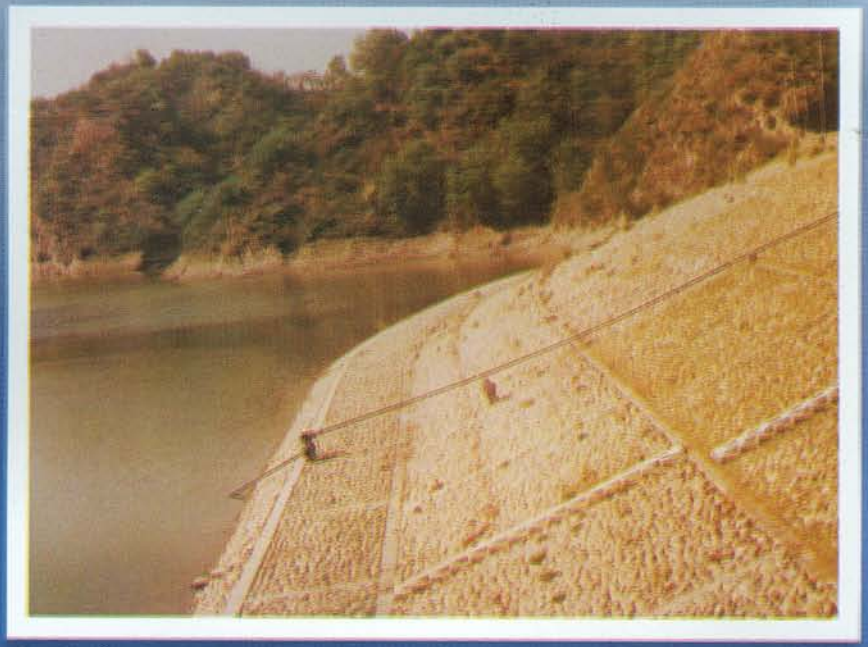
Fig. 5 - Composition of Plankton in Nangal Reservoir.



Composition of Periphyton in Nangal Reservoir.

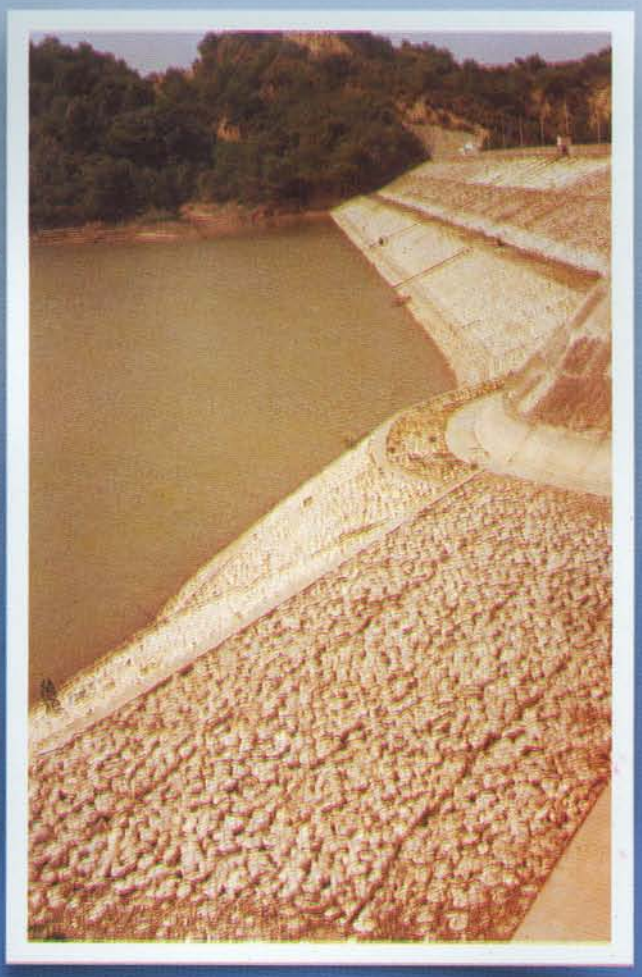


View of Janajuri Reservoir



View of Dholbaha Reservoir

View of Nangal Reservoir



View of Maili Reservoir