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FINAL REPORT

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON ECOLOGY AND FISHERIES OF FRESHWATER RESERVOIRS

RIHAND

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ALL INDIA COORDINATED RESEARCH PROJECT ON ECOLOGY AND FISHERIES OF FRESHWATER RESERVOIRS

FINAL REPORT
1971-1981

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FOREWORD

The country has vast reservoir resources estimated at 3 million ha. The fish production from these reservoirs numbering 500 or so, of which 50 are large impoundments averages 10 kg/ha/yr. This represents only a small fraction of the fishery potential. In order to fill this gap and improve the fish production in reservoirs in the country, an All India Coordinated Research Project on Reservoir Fisheries was launched in the year 1971 with the avowed purpose of enlarging our horizon of understanding of the ecological principles and ecological production functions that govern reservoirs in the country and evolve suitable management policies so that the results that may emerge from these studies will be not only relevant to any reservoir under study under the Project but the results could be extended *a posteriori* to other reservoirs of similar eco-morphological parameters. The studies carried out in Rihand Dam have thrown considerable information on soil features of the basin, physico-chemical parameters of water, biotic communities including plankton, benthos, periphyton, ichthyofauna, fisheries, stock structure of economic fishes, etc. leading to suitable management policy which could raise the production 4-fold, if adopted. In spite of frequent staff changes at the beginning, the programme gained momentum after a year under the able and dynamic supervision of Shri V.R. Desai. His fellow colleagues put forth their very best effort. Even those who worked briefly gave their best. The present report represents their dedicated work. I record my appreciation of the excellent work done by these workers and also for the help rendered by the State Fisheries Department. I like to make a special mention of ever-willing help received from the Director of Fisheries, Government of Uttar Pradesh, Dr. Y.R. Tripathi and Shri A.N. Singh, Deputy Director of Fisheries. I do sanguinely hope that the State in line with recommendations would take up development measures.

A.V. Natarajan
Director

CONTENTS

1 INTRODUCTION

A number of river valley development projects have been taken up in India since independence which have led to the creation of a good many impoundments. Some of these reservoirs are meant for irrigation, others for hydel generation, still others for storage/flood control/navigation while some are multipurpose reservoirs. Presently there are about 50 large and 475 medium and small reservoirs covering an approximate water surface area of 3 million ha which is likely to double itself in the next two decades. These water bodies **offer** a picture of wide-ranging ecological variety and are an important source of fish protein. However, only a fraction of their potential is currently being exploited, the average fish production being 7 kg or so per ha per year.

Hora (1949) conducted a pre-impoundment survey of a 100-km stretch of Rihand river from the proposed dam site at Pipri to its confluence with river Sone at Chopan. After the impoundment, Tripathi (1968) observed the breeding of Indian major carps in the Lotic sector of the reservoir. Motwani (1970) published an account of the studies conducted by the Department of Fisheries, Government of Uttar Pradesh, incorporating observations on hydrobiology, fish fauna, and experimental and commercial fishing. With a view to understanding the ecology and dynamics of fish stocks for obtaining sustained optimum fish production from the reservoir, the Central Inland Fisheries Research Institute (ICAR) established a centre of the All India Coordinated Research Project on the Ecology and Fisheries of Freshwater Reservoirs at Rihand in May 1971 and the present report is based on the investigations conducted by this Unit from 1971-81 (Fig. 1 & 2).

2 MORPHOMETRY OF RIHAND RESERVOIR

Rihand reservoir has been formed as a result of a dam across Rihand (also known as Rend or Renu) river near village Pipri in District Mirzapur of Uttar Pradesh. The Rihand is a tributary of the Sone which in turn joins the Ganga. Rihand originates from the hills of the Rewa Division of Madhya Pradesh draining a catchment area of 13,344 sq km. The confluence of Rihand with the Sone lies 45 km below the dam at a place known as Chopan (Fig. 3). While three-fourth of the reservoir area falls in Uttar Pradesh, the rest is in Madhya Pradesh. Rihand is a hydel project with an average water-spread area of 30,148 ha (FRL + DSL/2)

Hora, S.L. (1949). J. Zool. Soc. India, 1 : 1-7

Tripathi, Y.R. (1968). Proceedings of the seminar on production of quality fish seed for fish culture. CIFRI, Barrackpore. 1 & 2 Nov., 1968.

Its annual water level fluctuation is about 15 m, the mean depth at FRL being 24 m.

The reservoir has a shore line length of 561.33 km and a shore development of 7.04 at FRL, the latter pointing to a high degree of shore irregularity. The volume development of the reservoir being less than unity (0.89) indicates a convex character of the reservoir basin.

The data on Rihand are summarised below :

1. Latitude : $24^{\circ}1'$ & $83^{\circ}3'$ E

2. Year of construction

   (a) Commencement : 1956
   (b) Completion : 1962

3. River bed level at dam site : 190 m

4. Outlet levels

   (a) Under sluice : 216 m
   (b) Penstock : 224 m
   (c) Spill-way crest: 260 m

5. Area and capacity

Area and capacity	Level (m)	Area(ha)	Capacity(million acre feet)*
Dead storage (DSL)	236	13,759	1.3
Full reservoir(FRL)	268	46,538	8.6
Maximum submergence	271	50,594	9.8

6. Average annual water level fluctuations : 15 m

7. Maximum length of the reservoir : 48 km

8. Catchment : 13,344 sq km

9. Annual expected inflow : 5.1 million ac.ft.

10. Purpose : Power generation

* one acre feet =0.12335 ha-m

Motwani, M.P. (1970). Report on the fish and fisheries of Rihand reservoir. Department of Fisheries, Uttar Pradesh, Lucknow.

3 SAMPLING PROCEDURE

3.1 Zonal demarcation

The sampling and analytical procedure was in accordance with the "Methodology on reservoir fisheries investigations in India" by Jhingran et al. (1969).

The reservoir was arbitrarily divided into three transverse sectors viz. Lentic, Intermediate and Lotic (Fig.3). While the Lentic sector corresponded to the dam area characterised by deeper and stagnant water conditions, the Lotic to the confluence of the reservoir and the river with shallow and flowing water. The sector in between the Lentic and Lotic was marked as Intermediate. No bays and coves exist in Rihand reservoir. In each of the above three sectors, sampling was done at two centres, opposite each other, one on either bank thus covering six sampling centres in the entire stretch of the reservoir. At each centre, the samples were collected from three zones viz. littoral - shallow, being nearer to the bank; sub-littoral - slightly deeper, being a little away from the bank; and, profundal - deepest, being far away from the bank. While the Lentic and Intermediate sectors are deep with steep gradient and rocky substratum covered with dense forest, the Lotic sector is less rocky having shallow and gentle gradient with a substratum of loose clayey soil (Figs. 4 & 5).

3.2 Surface water

Surface water samples were taken in the littoral, sublittoral and profundal zones of the Lotic, Intermediate and Lentic sectors. From January 1973 to June 1974, the samples were collected once a month from all the three sectors covering the entire reservoir along one of its banks. The opposite bank was sampled in the subsequent month and the two banks were thus covered in alternate months. This monthly sampling schedule was later changed to a quarterly schedule from July 1974 when both the banks in one sector were sampled in a month. Thus each sector was sampled four times in a year with a gap of two months (Figs. 6 & 7).

Jhingran, V.G., A.V. Natarajan, S.M. Banerjea and A. David (1969). Bull. cent. Inland Fish. Res. Inst., Barrackpore (12) : 109 p.

Diurnal variations of chemical constituents were also observed at 6-hr intervals in the Lotic sector.

3.3 Sub-surface water

Sub-surface sampling was undertaken from January 1975 with Van Dorn water sampler manufactured by the General Engineering and Scientific Works, Berhampur (Ganjam), Orissa. Depth-wise sampling was done in profundal zone only at 0, 1 and 3 and subsequently at every 3 m but temperature, pH, dissolved oxygen, free CO_2 and HCO_3 were recorded at a depth of every one meter during the summer months (April - June).

3.4 Basin soil

At least three random soil samples were collected by an Ekman's dredge from every 26 km^2 in each of the three sectors during pre-monsoon (May-June) and post-monsoon (November-December) months. Soil samples were analysed for organic carbon, available nitrogen, available phosphorus and calcium carbonate and also for sand, silt and clay contents.

3.5 Primary production

Primary production studies using dark and light bottles were made separately in each of the three sectors of the reservoir in littoral, sub-littoral and profundal zones. Depth-wise observations were recorded at every meter upto compensation level (3 m). At each depth, three sets of replicates were used and the bottles exposed for a period of 12 hours from sun-rise to sun-set. (Fig.8).

3.6 Plankton

Plankton was collected by a net made of nylo-bolt (No.25). Vertical plankton hauls were taken from littoral, sub-littoral and profundal zones of the Lentic, Intermediate and Lotic sectors. Each sector was sampled on both the banks during a month, the remaining two sectors being sampled along one bank only. Thus altogether 12 samples were collected in each month covering the entire stretch of the reservoir. Apart from vertical plankton hauls, horizontal hauls were also taken from different zones of three sectors for qualitative analysis. Depthwise collection for plankton were also made using Van Dorn sampler. (Figs.7, 9 & 10).

3.7 Bottom biota

Bottom biota samples were collected at 0, 2, 4, 6, 8, 10, 15, 20, 30, 40 and 50 m depths from the three sectors of the reservoir. Each sample constituted a minimum of three hauls taken randomly.(Figs. 11 & 12).

3.8 Periphyton

Periphyton samples were collected every month from one sector only covering both the banks and thus the three sectors were sampled in three months. At least three samples, each of 1 sq cm, were picked up from tree trunks and boulders submerged in water and preserved separately in 2% formalin. In the laboratory, the periphytic forms were gently detached from the substratum through mild scrapping. The volume was noted after centrifuging. The sample was then transferred to a beaker containing a little water and its volume made up to 100 ml by adding water. A sample of 1 ml was then taken in a Sedgwick-Rafter plankton counting cell and examined. Based on the number of forms counted in 10 squares, the number per square was determined and the total number per sq cm (u/cm^2) calculated by the following formula :

$$\text{Total numbers/sq cm} = a \times 1 \times 1000$$

where a = number of forms/square

1 = volume (ml) after sedimentation

The volume (ml/cm^2) was estimated directly from the volume after sedimentation.

3.9 Observations on breeding

The eggs, larvae and fry, available only in the Lotic sector of the reservoir, were collected during monsoon months (July and August) by operating 3-5 Midnapore spawn collection nets of 3.125 mm mesh. (Fig.13) The spawn was reared in the field till identifiable stage. The day-to-day collection of spawn was also examined microscopically for quality. Within 15-20 days of breeding, fish fry were also available in the shallow marginal pockets of the reservoir which were collected by a Jaunpur drag net. The collections of fry so made were analysed qualitatively and the species composition compared with that ascertained from rearing of eggs and larvae.

3.10 Estimation of fish yield

The commercial catch of Rihand reservoir brought from different fishing sites is landed only at one centre known as Kuldumri situated along the northern bank of the reservoir in the Intermediate sector. The data on fish catch, species composition (by weight and number) and fishing effort (number of nets, boats and men), maintained by the staff of State Fisheries Department posted at the landing centre (Fig.14), were collected by visiting the landing centre twice a week during the period of commercial fishing. The visit was also used for collection of fish specimens and other data for biological studies.

The yield/ha/annum of the reservoir was calculated by dividing the total yearly yield in kg by the average water area. (30,148 ha) of the reservoir.

3.11 Fish fauna and trash fishes

Besides collecting the specimens from commercial catch for faunistic study, spawn and fry collections made in the Lotic sector during the monsoon months were also utilized. Samples were also collected by operating a fry net in shallow marginal pockets of the reservoir in Intermediate sector.

3.12 Commercial gear

During November 1973 to March 1974, spot sampling of commercially operated gill nets was undertaken every month to collect the data on net-wise catch and length and girth of fish in relation to the mesh bar.

3.13 Experimental fishing

Project work on experimental fishing included operation of surface gill nets with mesh bars ranging from 20 to 150 mm. About 18 pieces of such gill nets were fabricated by putting 70 m of webbing on 35 m of head rope (50% hanging coefficient). These pieces were tied together separately in five sets in increasing order of the mesh bar. Thus each set was a multi-meshed net with the following distribution :

Code no. of set	Distribution of mesh bars (mm)	No. of pieces
A	20, 25, 30 and 35	4
B	40, 45, 50 and 55	4
C	60, 65, 70 and 75	4
D	80, 85 and 90	3
E	130, 140 and 150	3
		18

The above gill nets were planned to be operated for 4 days in each of the three sectors totalling to 12 days/month in the entire stretch of the reservoir (Fig.15).

Data on experimental fishing conducted by the State Fisheries Department from October 1973 to February 1974, using on an average 25-30 surface gill nets per day of different types and mesh bars ranging from 50 to 180 mm, were also collected.

3.14 Fishery biology

Studies on the food composition of major carps and trash fishes and the maturity and fecundity of major carps were undertaken. The age and growth of C. catla and catla-rohu hybrid were studied by the examination of scales.

3.15 Meteorological and reservoir data

Meteorological data on rainfall and wind speed, and, the data on water level, water capacity, inflow/outflow of water and evaporation loss in the reservoir were collected from the Irrigation Department of Uttar Pradesh at Rihand Dam. The maximum and minimum air temperatures were noted everyday in the laboratory.

4 METEOROLOGICAL OBSERVATIONS

4.1 Air temperature

Monthly average maximum and minimum air temperature were recorded from April 1973 to March 1978. (Table I). While the five yearly average maximum temperature ranged from 26.7°C (January) to 45.8°C (June), minimum temperature fluctuated between 6.3°C (January) to 25.6°C (May).

TABLE I

MAXIMUM AND MINIMUM AIR TEMPERATURE (°C) AT RIHAND RESERVOIR (1972-73 to 1977-78)

Months	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		Average	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
April	33.5	25.3	45.2	21.0	43.5	22.0	43.5	22.0	42.5	19.2	43.0	22.0	41.9	21.9
May	46.5	25.0	47.0	27.0	46.0	27.5	45.2	27.0	44.4	25.0	44.5	22.0	45.6	25.6
June	48.5	26.8	46.0	26.0	44.0	26.0	47.5	22.5	43.5	24.0	45.5	24.5	45.8	25.5
July	41.0	25.0	42.5	24.0	37.0	22.8	37.5	23.0	42.0	24.0	38.5	23.0	39.7	23.6
August	41.5	23.5	47.0	24.5	37.5	24.0	39.0	22.0	36.5	24.0	37.0	24.0	39.7	23.7
September	36.8	19.0	35.5	23.5	40.0	23.5	36.5	24.2	35.5	22.7	35.0	22.5	36.5	22.6
October	35.0	16.5	34.0	17.0	37.0	17.0	35.5	16.5	35.3	18.0	34.0	17.5	35.1	17.1
November	30.5	12.5	33.5	11.0	30.0	12.5	31.5	9.5	32.8	12.5	33.0	14.5	31.9	12.1
December	26.5	11.5	26.0	5.5	26.5	7.5	26.0	8.0	27.0	7.5	28.0	8.0	26.7	8.0
January	31.0	6.5	28.0	6.0	25.0	7.0	27.5	6.5	28.0	6.0	27.5	6.0	27.8	6.3
February	35.0	9.8	34.0	5.0	31.5	8.0	32.0	10.0	32.5	8.5	29.0	7.0	32.3	8.0
March	41.0	12.3	38.5	14.0	38.5	16.5	37.4	14.0	40.0	14.0	34.5	13.5	38.3	14.0
Range	26.5- 48.5	6.5- 26.8	26.0- 47.0	5.0- 27.0	25.0- 46.0	7.0- 27.5	26.0- 47.5	6.5- 27.0	27.0- 44.4	6.5- 25.0	27.5- 45.5	6.0- 24.5	26.7- 45.8	6.3- 25.6

4.2 Rainfall

The rainfall around Rihand is caused by South-West monsoon only. The total yearly rainfall during 1972-73 to 1977-78 ranged from 107.45 to 260.91 cm (Table II). On an average, 86% of precipitation was recorded between July and September. The precipitation was normally high in July-August except in 1973-74 when it was the poorest in July. Though the rainfall was low in 1976-77 (95.60 cm), the precipitation was high in July-August.

4.3 Wind velocity

The average wind velocity (km/hr) during 1972-73 to 1976-77 ranged from 1.06 km/hr (1972-73) to 1.98 km/hr (1975-76). As seen from the monthly trend of wind velocity, it progressively increased from January (0.67 km/hr) to May (1.74 km/hr), remained highest in June-July (2.69-2.70 km/hr), moderate in August-September (2.43-2.50 km/hr) and gradually decreased from October to attain its minimum intensity in December (0.46 km/hr).

5 PHYSICAL FEATURES OF RIHAND RESERVOIR

5.1 Water level

Monthly average reservoir water level during 1972-73 to 1977-78 is given in Table III. The yearly average water level ranged from 248.22 m (1974-75) to 258.43 m (1976-77). The water level which decreased from 257.36 m (1972-73) to 248.22 m (1974-75), increased to 258.43 m (1976-77) and again dropped to 256.02 m (1977-78).

5.2 Inflow of water

Monthly monsoon inflow recorded during 1972-73 to 1977-78 is shown in Table IV. The yearly inflow of water varied from 2.650 m.a.ft. (1974-75) to 7.232 m.a.ft. (1977-78). Going by the direct impact of rainfall, the inflow was obviously high during monsoon months (July to September). However, the inflow did not bear any relationship with the rainfall recorded at Rihand. The poor inflow of 1974-75 (2.650 m.a.ft.) was the lowest record in 14 years after the formation of the reservoir.

5.3 Water capacity

The monthly average water capacity of the reservoir indicated direct relation with the average water level.

TABLE II

RAINFALL (cm) AT RIHAND RESERVOIR (1972-73 TO 1977-78)

Months	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78
April	-	-	4.50	-	5.28	-
May	-	0.05	-	-	1.66	-
June	0.96	6.20	6.47	10.71	3.93	36.00
July	42.59	20.17	40.00	51.17	49.49	76.13
August	64.90	30.15	32.76	74.02	15.03	51.02
September	15.83	41.70	49.40	14.79	20.21	62.98
October	6.24	8.98	1.16	2.25	-	4.42
November	4.20	0.20	3.36	-	-	1.16
December	0.10	-	0.10	-	-	1.62
January	0.22	-	1.46	0.42	-	5.06
February	2.34	-	-	-	-	16.56
March	-	-	1.68	-	-	5.96
Total	137.38	107.45	140.89	153.36	95.60	260.91

TABLE III

WATER LEVEL (m) OF RIHAND RESERVOIR (1972-73 TO 1977-78)

Months	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78
April	259.23	249.38	246.61	244.23	262.08	245.11
May	257.06	246.92	245.76	243.14	260.34	243.76
June	254.70	244.74	242.57	242.04	258.70	242.90
July	255.17	243.21	247.04	246.91	257.76	251.02
August	258.16	244.43	251.39	256.62	260.93	260.73
September	262.00	250.03	253.05	265.88	263.25	263.56
October	262.57	253.70	252.21	267.26	262.25	264.35
November	260.46	253.82	251.26	267.56	259.99	263.34
December	258.38	252.19	249.76	266.82	258.42	261.91
January	256.00	249.17	247.13	265.76	255.59	259.84
February	252.96	247.90	245.07	264.53	252.86	258.29
March	251.67	247.06	244.80	263.22	249.00	257.48
Average	257.36	248.54	248.22	257.83	258.43	256.02

TABLE IV

WATER INFLOW (m.a.ft) IN RIHAND RESERVOIR
(1972-73 TO 1977-78)

Months	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78
April	-	-	-	0.026	1.088	-
May	-	-	-	0.009	0.053	-
June	-	0.075	-	0.134	0.085	0.543
July	1.396	0.390	1.086	1.343	1.029	2.655
August	2.226	1.102	1.041	3.674	1.469	2.271
September	0.983	1.589	0.223	1.020	0.743	0.983
October	0.046	0.680	0.103	0.513	0.312	0.320
November	0.035	0.091	0.067	0.072	0.033	0.152
December	0.048	0.085	0.028	0.050	-	0.093
January	-	0.030	0.054	0.047	-	0.022
February	-	0.014	0.011	-	-	0.108
March	-	0.014	0.037	0.043	-	0.085
Total	4.734	4.070	2.650	6.931	4.812	7.232

The yearly average water capacity recorded for the period 1972-73 to 1977-78 varied from 3.05 m.a.ft. (1974-75) to 5.53 m.a.ft. (1975-76).

Data on rainfall, inflow, water level and water capacity (Fig. 16) clearly showed that the low reservoir level in 1973-74 and 1974-75 was the result of poor monsoon inflow of the corresponding years.

5.4 Outflow of water

The reservoir never attained its full level during the 8-year period from 1972-73 to 1980-81, and the water was discharged through penstocks only. The outflow was regulated according to the requirement of water for power generation. The quantum of water outflow during 1972-73 to 1977-78 was as below :

Year	Outflow of water (cusecs)
1972-73	67,44,554.63
1973-74	58,09,555.57
1974-75	29,78,578.66
1975-76	25,50,217.00
1976-77	73,91,124.00
1977-78	48,59,197.00

5.5 Evaporation

The loss of water through evaporation, as seen from the monthly averages of five years (1972-73 to 1976-77), progressively increased from January (0.016 m.a.ft.) to August-September (0.054 m.a.ft.) and decreased from October (0.026 m.a.ft.) to December (0.010 m.a.ft.).

6 PHYSICO-CHEMICAL FEATURES OF SOIL

Data on sectoral soil composition during pre-monsoon and post-monsoon months are given in Table V. Going by the values it is obvious that organic carbon (0.083-1.133%) is medium while available nitrogen (15.5-30.5 mg/100 g) and availabl phosphorus (1.1-2.3 mg/100 g) are poor.

Organic carbon, available phosphorus, available nitrogen and $CaCO_3$ were high during post-monsoon months. The increase in their values was due to the washings from the cultivated catchment area brought in by the inflowing river water. While sand and silt decreased during post-monsoon

TABLE V

SECTORAL PHYSICO-CHEMICAL COMPOSITION OF BASIN SOIL OF RIHAND RESERVOIR (1974-76)

Sector	pH	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)	Available P_2O_5 (mg/100g)	Available N (mg/100g)	Organic Carbon (%)
			Pre-monsoon 1974					
Lentic	6.6-7.0	0.87	31.7	19.5	48.7	2.3	23.1	0.609
Intermediate	6.0-6.4	0.45	41.2	14.0	44.7	2.3	27.1	0.709
Lotic	6.3	0.58	28.0	32.0	40.0	1.5	25.9	0.826
Average		0.57	33.6	21.8	44.5	1.8	25.9	0.714
			Post-monsoon 1974					
Lentic	7.5-8.0	3.62	14.5	10.4	75.0	1.1	17.7	1.043
Intermediate	7.2-8.0	4.83	16.8	10.9	72.2	2.0	26.6	0.774
Lotic	7.0	2.25	16.2	14.3	69.4	1.7	24.9	0.930
Average		4.37	15.8	11.9	72.2	1.8	24.9	0.842
			Pre-monsoon 1975					
Lentic	7.0-8.5	3.07	30.0	22.3	47.6	1.1	18.4	0.750
Intermediate	6.8-8.0	2.33	36.7	17.6	45.5	1.1	26.8	0.688
Lotic	7.0	2.75	32.6	24.1	43.2	1.2	15.5	0.593
Average		2.56	33.1	21.3	45.4	1.1	22.7	0.618
			Post-monsoon 1975					
Lentic	6.3	2.45	10.7	30.0	59.2	2.0	25.9	1.133
Intermediate	6.5-7.0	2.13	17.8	18.6	63.6	1.8	30.1	0.908
Lotic	7.5	2.75	15.4	29.3	55.2	2.0	30.5	0.885
Average		2.30	14.6	25.9	59.3	1.9	28.9	0.969
			Pre-monsoon 1976					
Lentic	7.0-7.3	3.87	19.2	21.2	59.5	1.2	15.6	0.083
Intermediate	6.8-7.9	2.46	18.5	18.2	63.2	1.3	24.7	0.097
Lotic	7.0	2.32	19.2	39.2	41.5	1.5	20.1	0.102
Average		2.67	19.0	26.2	54.7	1.3	22.4	0.095

months, the clay content increased considerably after rains due to its slow settling characteristics. The overall percentage of clay was quite high in the reservoir.

7 PHYSICO-CHEMICAL FEATURES OF WATER

7.1 Surface water

7.1.1 Seasonal and sectoral variations

Water temperature varied in the range of 19.9-31°.1 C and water transparency 1.8-28.5 cm, the latter being the lowest during monsoon and highest during summer. Water was more turbid in the Lotic sector during summer and monsoon and in the Lentic and Intermediate sectors during the winters. The overall transparency was quite low (average 14.58 cm) and the reservoir remained turbid during most of the months of the year due to a high percentage of clay.

pH varied from 7.0-8.8 (average 7.9), being low during the monsoons due to inflowing water carrying a high amount of carbon dioxide. Dissolved oxygen ranged from 2.8-10.2 ppm (average 7.54 ppm) and its saturation ranged from 77.4 - 107.5%. Oxygen saturation was always over 50% and at no time it was less than 3 mg/l. Dissolved oxygen was low from June to October largely due to the inflowing water poor in oxygen. Free CO_2 varied from 3.5 to 34.0 ppm. High values of CO_2 were observed during July-October.

Total alkalinity ranged from 28.0 to 60.0 ppm (average 43.87 ppm) and was available in the form of bicarbonates only, carbonates being absent in the presence of free CO_2. Bicarbonate value was high in summer due to evaporation and low in monsoon owing to the effect of dilution. Total hardness varied from 8.4 to 21.6 ppm (average 15.7 ppm) and followed the trend of bicarbonates. Ca^{++} varied in the range of 6.2-14.8 ppm while Mg^{++} from 1.08-5.24 ppm. These cations also followed the trend of bicarbonates. PO_4-P ranged from traces-0.65 ppm (average 0.079 ppm) while NO_3-N from 0.15-0.70 ppm (average 0.383 ppm) and NH_4-N from traces-1.45 ppm (average 0.296 ppm). SiO_2 ranged from 1.6 to 14.0 ppm, the maximum content of silicate in August was directly associated with monsoon floods and turbidity. Chlorides varied from 6.0 to 20.0 ppm and the dissolved organic matter varied in the range of 1.6 - 20.0 ppm. Specific conductivity varied in the range of 50.61-138.50 x 10^{-6} mhos (average 92.24 micromhos), being the maximum in April. The overall specific conductivity was high during summer and premonsoon (March to July) but low during post-monsoon and winter months.

Lotic sector showed higher values of bicarbonates, iron, organic matter and phosphate. Calcium, magnesium, nitrate and specific conductivity were high in the Lentic sector. The chemical features of various sectors tend to indicate the relative richness of Lotic sector Table VI). The nutrient status of the reservoir water was high during summer, particularly in March.

It is thus seen that reservoir water quality is good in respect of PO_4-P and favourable in respect of NO_3-N, while total alkalinity, total hardness and specific conductivity are below average.

7.1.2 Diurnal variations in Lotic sector

Diurnal variations of physico-chemical conditions of water in the Lotic sector did not show any remarkable six hourly variation during September, December, March and June.

7.2 Subsurface water

7.2.1 Thermal stratification

Subsurface sampling for water temperature gave an indication of thermocline in the Lentic sector (Fig. 17). With the onset of summer (March-April), the values of water temperature started declining from surface to bottom. By May-June, thermal stratification was well defined. The difference between surface and bottom temperature was of the order of 10°C in May 1975, 8.5°C in May 1976 and 9.5°C in May 1977. However, thermal stratification was short-lived and soon broken by the influx of flood water in July-August. No such stratification was observed during winters when temperature differences were 0.4°C only.

7.2.1.1 Depth of thermocline in relation to water level

The depth characteristics of thermocline were found to have a correlation with water level of the corresponding year. While in May 1975, the thermocline was superficial (5-7 m) when the reservoir level was low (242.64 m), in May 1976 it was observed at 11-13 m when the reservoir level was high (260.34 m). Again in May 1977, with a low water level (243.76 m), the depth of thermocline was superficial (9-11 m).

TABLE VI

SECTORAL PHYSICO-CHEMICAL CHARACTERISTICS OF WATER OF RIHAND RESERVOIR (1975-76 TO 1977-78)

Characteristics	Lentic	Intermediate	Lotic
Water transparency(cm)	10.5 - 28.5	5.5 - 26.5	1.8 - 25.0
Water temperature (°C)	19.9 - 31.1	21.5 - 31.0	20.5 - 30.5
pH	7.6 - 8.2	7.0 - 8.3	7.0 - 8.8
Dissolved O_2 (ppm)	5.2 - 8.8	5.2 - 9.4	2.8 - 10.2
Free CO_2 (ppm)	5.0 - 33.0	3.5 - 34.0	2.0 - 28.0
HCO_3 (ppm)	30.0 - 43.0	24.0 - 48.0	28.0 - 60.0
NH_4-N (ppm)	Traces - 1.45	Traces- 1.40	0.08- 1.20
NO_3-N (ppm)	0.17- 0.60	0.15- 0.42	0.25- 0.70
PO_4-P (ppm)	Traces - 0.25	Traces- 0.65	Traces- 0.20
Ca^{++}(ppm)	8.7 - 14.3	6.2 - 13.6	6.8 - 14.8
Mg^{++}(ppm)	1.08- 5.24	1.35- 3.72	1.95- 4.78
Silicate (ppm)	2.4 - 14.0	4.0 - 10.0	1.6 - 14.0
Fe^{+++} (ppm)	0.018 -0.096	0.012-0.084	Traces- 0.18
Chloride (ppm)	8.0 - 20.0	7.0 - 15.0	6.0 - 16.0
Total hardness (ppm)	11.6 - 19.6	8.4 - 18.1	11.4 - 21.6
Dissolved organic matter (ppm)	1.6 - 9.8	2.0 - 6.4	1.6 - 20.0
O_2 saturation (%)	58.36-112.76	59.49-112.56	37.58-130.61
Specific conductivity (micro-mhos/cm)	50.61-138.50	59.75-126.32	59.75-131.58

7.2.2 Chemical stratification

The depthwise analysis of Lentic water in respect of dissolved O_2, free CO2, HCO_3, pH and specific conductivity also gave an indication of weak chemical stratification in Rihand reservoir. While dissolved O_2, pH, HCO3 and specific conductivity decreased from surface to bottom, free CO_2 showed a reversible trend. This variation, although apparent in April and May, was very significant in June (Table VII) when pH (S-8.0, B-79), dissolved oxygen (S*-8.3, B*-5.1 ppm), HCO_3 (S-44.0, B-34.0 ppm) and specific conductivity (S-139.97, B-106.14 micro-mhos) showed declining values excepting free CO_2 (S-8.0, B-16.0 ppm) which followed an increasing trend. Depthwise analysis of water revealed more or less uniform values from surface to bottom in December and January showing an absence of biogenic chemical stratification during winter months.

Despite the presence of a strong thermal stratification in Rihand reservoir, there was only a slight decline in oxygen from surface to bottom with always enough oxygen in the lower depths (3.4 ppm and above) showing poor availability of biota. The decomposition processes at the bottom were also not rapid i.e. the tropholytic activities were of a low order. This can also be confirmed from pH of water which did not show much variation in tropholytic regions. Due to the presence of free carbon dioxide round the year and non-availability of carbonate at the bottom, the bicarbonate and specific conductivity do not show any increase in the tropholytic region. But in the upper layers the process of evaporation causes an increase in these parameters. The presence of strong thermal stratification does not allow the two layers to mix and the depth profile show decreasing trend from surface to bottom. All these observations tend to show a low productive character of the reservoir.

While the existence of chemocline, more strikingly oxygen stratification, was prolonged and extended upto October in 1974, the duration of stratification was very short in subsequent years (1975 to 1977) lasting only upto July (Table VIII). Correlating the yearly monsoon inflow with the duration of chemocline it has been observed that the stratification could persist upto October in 1974 due to poor monsoon

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* S - Surface; B - Bottom

TABLE VII

PHYSICO-CHEMICAL FEATURES OF SUB-SURFACE WATER IN LENTIC SECTOR OF RIHAND RESERVOIR

Depth (m)	January 1977						June 1977					
	Water temperature (°C)	pH	DO (ppm)	CO_2 (ppm)	HCO_3 (ppm)	Specific conductivity (micromhos)	Water temperature (°C)	pH	DO (ppm)	CO_2 (ppm)	HCO_3 (ppm)	Specific conductivity (micromhos)
S	20.0	8.0	7.6	8.0	38.0	69.99	30.8	8.0	8.3	8.0	44.0	139.97
1	20.0	7.8	7.6	8.0	38.0	71.51	30.8	8.0	8.3	8.0	44.0	139.97
4	20.0	7.8	7.6	8.0	36.0	69.99	30.5	8.0	8.3	8.0	44.0	139.97
7	20.0	7.8	7.6	8.0	36.0	69.99	28.7	8.0	7.8	10.0	44.0	124.13
10	20.0	7.8	7.6	8.0	36.0	69.99	26.5	8.0	7.0	10.0	42.0	121.83
13	20.0	7.8	7.6	8.0	36.0	69.99	24.9	7.9	7.0	10.0	40.0	117.48
16	19.5	7.8	7.6	8.0	36.0	70.74	23.2	8.0	6.4	10.0	40.0	124.13
19	19.5	7.8	7.6	8.0	36.0	71.51	22.0	8.0	6.4	12.0	38.0	109.64
22	19.5	7.8	7.4	9.0	36.0	69.99	21.5	8.0	6.4	12.0	38.0	106.14
25	19.5	7.8	7.4	9.0	36.0	71.51	21.5	8.0	5.8	12.0	36.0	106.14
28	19.5	7.8	7.4	9.0	36.0	67.82	21.5	8.0	6.4	13.0	36.0	106.14
31	19.5	7.8	7.4	9.0	36.0	67.13	21.5	8.0	6.4	12.0	36.0	106.14
34	19.5	7.8	7.4	9.0	35.0	65.79	21.5	8.0	5.8	14.0	36.0	106.14
37	19.5	7.8	7.4	9.0	35.0	65.79	21.2	7.9	5.8	15.0	36.0	106.14
40	19.5	7.8	7.4	9.0	35.0	65.79	21.2	7.9	5.8	15.0	35.0	106.14
43							21.2	7.9	5.1	16.0	34.0	106.14

TABLE VIII

CHEMICAL STRATIFICATION IN RIHAND RESERVOIR (1974-77)
IN RELATION TO MONSOON INFLOW

YEAR	1974		1975				1976				1977			
Inflow (m.a.ft.)	2.61		6.89				4.90				7.02			
Parameters	October		July		October		July		October		May		October	
	S	B	S	B	S	B	S	B	S	B	S	B	S	B
Dissolved oxygen(ppm)	7.4	3.4	6.2	4.0	6.4	5.8	6.8	4.8	6.8	5.4	8.3	4.8	8.2	6.8
Free carbon-dioxide(ppm)	5.5	9.0	28.0	30.0	33.0	31.0	8.0	12.0	7.5	11.5	8.0	16.0	5.0	7.0
pH	8.0	7.0	8.0	7.8	7.6	6.7	7.8	7.4	7.7	7.3	8.0	7.9	8.0	8.0
Bicarbonate (ppm)	33.5	37.0	43.0	38.0	39.0	21.0	40.0	38.0	35.0	30.0	44.0	34.0	34.0	30.0
Specific conductivity (micro-mhos/cm)	84.4	92.2	117.5	107.9	74.8	41.1	95.3	84.0	84.7	68.8	140.0	106.1	72.2	50.6

inflow (2.61 m.a.ft.) in that year. As the magnitude of monsoon inflow was high (4.90 to 7.02 m.a.ft.) in the years 1975 to 1977, it caused sufficient turbulence and early disturbance of stratification in July. It is concluded from these observations that in Rihand reservoir the duration of chemocline depends on the magnitude of monsoon inflow, and moreover the reservoir exhibits both convection current (in the year of poor inflow) and inflow turbulence effect (in the year of higher inflow).

8 PRIMARY PRODUCTION

The gross primary production ($mgC/m^2/day$) varied in the range 37.17-750.00 in 1973-74, nil - 825.00 in 1974-75 and nil - 1022.72 in 1975-76. The net primary production ($mgC/m^2/12$ hrs) varied in the range 22.54 - 541.67 in 1973-74, nil - 416.60 in 1974-75 and nil - 475.00 in 1975-76. Monthly variation in the rate of carbon production in different sectors are shown in Table IX. The overall average for gross production was 387.04 and net production 161.44. The net primary production for 24 hrs (allowing for night respiration @ 0.5 respiratory coefficient) is 80.72. The primary production, estimated separately for the three sectors of the reservoir, showed seasonal and sectoral variation which fairly agreed with the trend of planktonic abundance. The net production was highest in the littoral zone due to a higher concentration of Microcystis ; the most dominant plankton of the ecosystem, while it was the lowest in the profundal zone. In the depth profile the net production was highest in surface water owing to the presence of Microcystis. The peak values of net production were found to coincide with plankton pulses of summer and winter. The negative production as observed sometimes is attributed to high turbidity of water which reduced the photosynthetic rate and also due to abundance of zooplankton.

Primary production was initially very high in 1972-73 due to the presence of Microcystis bloom but was low from 1973-74 to 1975-76 in its absence. The production increased in 1976-77 with the recurrence of Microcystis bloom and slightly dropped again in 1977-78 for want of a denser bloom. These observations tend to show that the primary production of Rihand reservoir is entirely governed by Microcystis abundance.

TABLE IX

MONTHLY VARIATION IN THE RATE OF CARBON PRODUCTION (mg C/m^3/day) IN DIFFERENT SECTORS OF RIHAND RESERVOIR

Months	Gross production			Net production		
	Lentic	Inter-mediate	Lotic	Lentic	Inter-mediate	Lotic
January	139.52	278.47	454.49	62.50	136.25	255.65
February	909.36	346.38	420.42	734.85	105.19	130.68
March	398.49	494.79	223.19	173.30	151.57	164.00
April	1786.06	580.87	562.50	1325.95	406.25	187.50
May	635.34	521.61	562.50	500.00	329.83	187.50
June	320.46	221.64	191.88	142.00	124.72	63.21
July	250.19	313.19	62.50	108.81	143.75	Nil
August	140.15	842.32	93.75	52.08	518.24	Nil
September	230.40	197.33	304.58	196.52	127.71	7.81
October	404.58	370.34	250.00	245.68	261.77	125.00
November	250.18	224.88	409.09	55.50	112.42	272.73
December	145.83	135.42	347.69	Nil	62.50	390.85
Average	457.54	377.27	323.55	299.76	206.68	148.74

9 PLANKTON

9.1 Vertical haul

9.1.1 Annual, seasonal and sectoral distribution

There was an overall dominance of phytoplankton in the reservoir of which Myxophyceae, represented mainly by Microcystis, was the most important. Other forms belonging to Chlorophyceae, Bacillariophyceae and Dinophyceae occurred occasionally. Zooplankton was primarily represented by Cyclops and Diaptomus among copepods; Daphnia, Ceriodaphnia, Moinodaphnia, Diaphanosoma, Chydorus, Macrothrix, Sida, Bosmina and Leptodora among cladocerans; Brachionus, Filinia, Polyarthra, Trichocerca and Keratella among rotifers; and, Difflugia among protozoans.

The average annual plankton concentration ranged from 1.92 ml/m^2 (1973-74) to 7.31 ml/m^2 (1976-77) the concentration in general being higher in the Lotic sector followed by the Intermediate (Table X). Ceratium formed a bloom in the Intermediate sector in February 1973-74 and 1974-75 while it appeared in abundance in March 1975-76. Microcystis blooms appeared in the Lentic sector in 1976-77 and in the Intermediate sector in 1977-78.

TABLE X

Plankton abundance in Rihand reservoir (1972-73 to 1977-78)

SECTORS

Years	Lentic		Intermediate		Lotic		Average	
	No. (units/m^2)	Volume (ml/m^2)	No. (units/m^2)	Vol. (ml/m^2)	No. (units/m^2)	Vol. (ml/m^2)	No. (units/m^2)	Vol. (ml/m^2)
1972-73	58,607	2.02	11,419	2.03	54,464	5.18	41,496	3.08
1973-74	4,704	1.38	5,561	2.24	2,593	2.15	4,286	1.92
1974-75	32,336	2.56	7,732	2.86	3,383	2.76	14,484	2.73
1975-76	8,800	2.45	24,643	4.18	23,349	4.43	18,930	3.68
1976-77	70,415	9.67	33,810	8.06	11,276	4.19	38,500	7.31
1977-78	3,839	1.54	62,735	10.16	25,484	5.74	30,686	5.81

Plankton showed two peaks in a year - summer and a winter pulse. The summer pulse (April to June) was observed in the Lentic and Intermediate sectors and was mainly dominated by phyto-plankton particularly Microcystis while the winter pulse (October to December) was observed in Lotic sector dominated by zooplankton. The biomass was always richer in the littoral zone followed by sublittoral and profundal zones. Poor planktonic abundance in the Lotic sector during summer and monsoon months and in the Lentic and Intermediate sectors during winter months was due to high turbidity.

An interesting feature in the distribution of plankton in the three sectors was that zooplankton progressively increased from Lentic to Lotic while phytoplankton gradually declined. Due to the discharge of the effluents of Kanoria Chemicals, the chloride contents were invariably high in Lentic sector but low in the Lotic sector on account of dilution by inflowing river water. Probably chlorinity determines the longitudinal distribution of zooplankton which have a higher concentration in the Lotic sector having a low chloride content.

It was also observed that plankton abundance on the north bank (Dam site, Kuldumri and Balleyari centres) was always higher than the south bank (Barai Dand, Bichhia and Pipra centres), probably due to favourable topography and high irregularity of the shore line.

9.1.2 Plankton abundance in relation to monsoon inflow

Plankton production in the reservoir was found to be regulated by the monsoon inflow. The plankton was poor in 1973-74 and 1974-75 due to reduced monsoon inflow but the biomass improved in 1975-76 with greater monsoon inflow. when increased abundance of free carbondioxide resulted in greater concentration of HCO_3 which worked as an additive factor to boost the plankton population.

9.2 Horizontal haul

Qualitative analysis of samples collected during the horizontal hauls indicated that though phytoplankton as a group was more abundant quantitatively as seen through vertical haul, it was qualitatively less abundant as compared to zooplankton (Table XI).

TABLE XI

QUALITATIVE DISTRIBUTION OF PLANKTON IN RIHAND RESERVOIR (1971-72 TO 1973-74)

LENTIC		INTERMEDIATE		LOTIC	
Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton
Microcystis, Melosira, Ceratium, Actinastrum, Coelastrum, Eudorina, Synedra, Botryococcus, Chroococcus, Chlorella, Aphanocapsa, Spirogyra, Chaetophora, Ulothrix and Anabaena	Cyclops, Diaptomus, Daphnia, Ceriodaphnia, Moinodaphnia, Chydorus, Simocephalus, Keratella, Brachionus Filinia, Difflugia, Bosmina, Eubranchipus, Gastropus, Ceratium, Sida, Trichocerca, Diaphanosoma, Acroperus, Alonella and Macrothrix	Microcystis, Melosira, Ceratium, Volvox, Eudorina, Chlorella, Fragilaria, Chroococcus, Actinastrum, Coelastrum, Ulothrix, Aphanocapsa, Pleurococcus, Anabaena and Spirogyra	Cyclops, Diaptomus, Diaphanosoma, Daphnia, Ceriodaphonia, Chydorus, Macrothrix, Keratella, Filinia, Trichocerca, Brachionus, Difflugia, Bosmina, Sida, Acroperus, Moinodaphnia, Polyphemus, Lecane, Ceratium, Leptodora, Gastropus and Polyarthra	Microcystis, Melosira, Denticula, Spirogyra, Synedra, Botryococcus, Fragilaria, Gyrosigma, Ceratium, Pediastrum, Actinastrum, Closterium, Volvox and Chlorella	Cyclops, Diaptomus, Chydorus, Ceriodaphnia, Brachionus, Ceratium, Difflugia, Trichocerca, Diaphanosoma, Keratella, Filinia, Daphnia, Acroperus, Polyarthra, Bosmina, Macrothrix and Moino daphnia

9.3 Subsurface plankton

During 1974-75, sub-surface sampling in three sectors covering a depth upto 42 m showed that plankton was available throughout the depth but the population decreased progressively from surface to bottom. The littoral zone had the richest plankton concentration.

10 BOTTOM BIOTA

10.1 Distribution and sectoral variation

The overall benthic population (32-70 units/m^2) of the reservoir was very poor (Table XII). The group was mainly represented by dipteran larvae like Chaoborus and Chironomus, caddisworms (Trichoptera), mayfly nymphs (Ephemeroptera), dragon-fly nymphs (Odonata), oligochaetes and sometimes bivalve shells of Corbicula. The concentration of oligochaetes was greater in the Lotic sector on account of clayey bed and was particularly high in May and again from November to February when this sector was stagnant in the absence of inflowing head water. During monsoon, when the Lotic sector turned turbulent its benthic population was reduced but the population of dipteran larvae increased in Intermediate and Lentic sectors.

TABLE XII

Sectoral distribution of bottom biota (units/m^2) in Rihand reservoir (1971-72 to 1976-77)

Year	Maximum depth upto which samples taken (m)	Lentic	Intermediate	Lotic	Average
1971-72	10	6	18	186	70
1972-73	10	60	66	38	55
1973-74	25	22	25	94	47
1974-75	45	20	16	155	64
1975-76	45	18	18	119	52
1976-77	45	34	31	31	32
Average		27	29	104	53

The overall benthic population in Intermediate and Lentic sectors was poor owing to their gravelly and rocky nature.

11 PERIPHYTON

The periphyton also indicated two pulses, one in summer (March-May) and the other in winter (October-December). There was no periphyton during June-July due to turbulence caused by the inflowing monsoon water in the reservoir. Periphyton set again when the reservoir was calm during post-monsoon months. The overall concentration was more in the Lotic sector and the forms mainly represented were Oscillatoria, Fragilaria, Gyrosigma and Navicula. Periphyton growth was poor in 1974-75 (530 u/cm^2) but improved in 1975-76 (1285 u/cm^2) and 1976-77 (1325 u/cm^2) and the trend agreed with that of plankton (Table XIII).

12 POLLUTION DUE TO FACTORY EFFLUENTS

The effluents released by Kanoria Chemicals Private Limited, Renukoot located on the northern bank of the reservoir (Fig.5) are discharged in the Lentic sector (Fig. 18). The factory manufactures caustic soda, bleaching powder and benzene hexachloride and the effluents are characterised by high chloride and free chlorine content. The pH is also low. Arora et al (1970) have recorded fish mortality due to chlorine bearing wastes. Studies on the pollutional effects of industrial effluents from Kanoria Chemicals have been studied by Panwar et al. (1979) in some details. These authors have also recorded heavy fish mortality in the summer of 1977. The dead fish comprised C. catla (2.5 - 3.0 kg) M. aor (0.3 - 0.6 kg) and C. mrigala (0.35 - 1.50 kg) and C. garua (72-85 g). Heavy mortality of carp and catfish fingerlings was also recorded during monsoon months. Absence of fish food organisms, plankton and bottom biota in the polluted zone confirms that the effluents which are highly toxic in nature are affecting the biomass in the reservoir.

13 AQUATIC PLANTS

The reservoir is devoid of aquatic plants on account of high clay turbidity and hence low transparency of water.

14 FISH FAUNA

A survey of fish fauna indicated the presence of 44 species belonging to 33 genera and 13 families (Table XIV). The fish fauna of Rihand river as reported by Hora (1949) before impoundment comprised 42 species belonging to 27 genera

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Arora, H.C., S.N. Chattopadhyaya and U.P.Sharma(1970). Environ Hlth., 12 : 260-72

Panwar, R.S. et al. (1979). Proc. Symp. Environ. Biol. : 465-79.

Hora, S.L. (1949). J. Zool. Soc. India, 1 : 1-7

TABLE XIII

PERIPHYTON DISTRIBUTION IN RIHAND RESERVOIR (1974-75 TO 1976-77)

Months	1974-75			1975-76			1976-77		
	Sector	Numbers (u/cm2)	Volume (ml/cm2)	Sector	Numbers (u/cm2)	Volume (ml/cm2)	Sector	Numbers (u/cm2)	Volume (ml/cm2)
April	-	-	-	Le	1106	0.4	Le	4700	1.3
May	-	-	-	Int	640	0.3	Int	3200	1.0
June				Lo	Nil	Nil	Lo	Nil	Nil
July	-	-	-	Le	Nil	Nil	Le	Nil	Nil
August	-	-	-	Int	566	0.4	Int	Nil	Nil
September	-	-	-	Lo	310	0.3	Lo	430	0.5
October	-	-	-	Le	950	0.8	Le	Nil	Nil
November	Int	180	0.2	Int	776	0.5	Int	*	*
December	Lo	840	0.7	Lo	1600	0.8	Lo	*	*
January	Le	380	0.4	Le	3000	0.8	Le	730	0.4
February	Int	374	0.3	Int	5264	1.3	Le	1750	0.6
March	Lo	880	0.5	Lo	2200	1.0	Le	2444	0.7
Average		530	0.4		1285	0.6		1325	0.9

Int = Intermediate; Lo=Lotic; Le = Lentic. *Not sampled.

TABLE XIV

FISH FAUNA OF RIHAND RESERVOIR

	Species	Project	Motwani	Hora
Family	NOTOPTERIDAE			
	Notopterus notopterus (Pallas)	+	+	+
	Notopterus chitala (Hamilton)	+	+	+
Family	CYPRINIDAE			
	Chela atpar (Hamilton)	+	+	-
	Chela laubuca (Hamilton)	+	+	-
	Oxygaster bacaila (Hamilton)	+	+	+
	Oxygaster gora (Hamilton)	-	+°	-
	Oxygaster boopis (Day)	-	-	+°
	Barilius barila (Hamilton)	+°	-	-
	Barilius bendelisis (Hamilton)	+	-	+
	Barilius bola (Hamilton)	-	+	+
	Danio devario (Hamilton)	-	+°	-
	Brachydanio rerio (Hamilton)	-	-	+°
	Esomus danrica (Hamilton)	+	-	+
	Rasbora daniconius (Hamilton)	+	+	+
	Amblypharyngodon mola (Hamilton)	+	+	-
	Aspidoparia morar (Hamilton)	-	+	+
	Chagunius chagunius (Hamilton)	-	+	+
	Tor khudree (Sykes)	-	-	+°
	Tor tor (Hamilton)	-	+°	-
	Puntius amphibius (Valenciennes)	-	-	+°
	Puntius conchonius (Hamilton)	-	+°	-
	Puntius sarana (Hamilton)	+	+	+
	Puntius sophore (Hamilton)	+	+	-
	Puntius ticto (Hamilton)	-	+	+
	Puntius titius (Hamilton)	-	+°	-
	Catla catla (Hamilton)	+	+	-
	Cirrhinus mrigala (Hamilton)	+	+	-
	Cirrhinus reba (Hamilton)	+	+	+
	Garra mullya (Sykes)	+	-	+
	Labeo bata (Hamilton)	+	+	-
	Labeo boggut (Sykes)	+	+	+
	Labeo calbasu (Hamilton)	+	+	+
	Labeo fimbriatus (Bloch)	-	-	+°
	Labeo pangusia (Hamilton)	-	-	+°
	Labeo rohita (Hamilton)	+	+	-
	Osteobrama cotio (Hamilton)	+	+	+
	Crossocheilus latius latius (Hamilton)	+	-	+

FISH FAUNA OF RIHAND RESERVOIR (CONTD)

	Species	Project	Motwani	Hora
Family	COBITIDAE			
	Botia davi Hora	+°	-	-
	Noemacheilus davi (Hora)	-	-	+°
	Noemacheilus denisonir Day	-	-	+°
	Noemacheilus zonatus	-	-	+°
	Lepidocephalus guntea balgara (Hamilton)	+	-	+
Family	SILURIDAE			
	Ompok bimaculatus (Bloch)	+	-	+
	Ompok pabda (Hamilton)	+°	-	-
	Wallago attu (Bloch & Schneider)	+	+	-
Family	SCHILBEIDAE			
	Clupisoma garua (Hamilton)	+	+	+
	Pseudeutropius murius (Day)	+	+	-
	Eutropiichthys vacha (Hamilton)	+	+	-
	Silonia silondia (Hamilton)	+	+	-
Family	SACCOBRANCHIDAE			
	Heteropneustes fossilis (Bloch)	+°	-	-
Family	BAGRIDAE			
	Mystus aor (Hamilton)	+	+	-
	Mystus bleekari (Day)	-	+°	-
	Mystus cavasius (Hamilton)	+	-	+
	Mystus seenghala (Sykes)	+	+	+
	Rita rita (Hamilton)	+	+	-
Family	AMBLYCIPITIDAE			
	Amblyceps mangois (Hamilton)	-	-	+°
Family	SISORIDAE			
	Bagarius bagarius (Hamilton)	+	+	+
	Gagata cenia (Hamilton)	-	-	+°
	Gagata itchkeea (Sykes)	+°	-	-
	Erethistes montana var. pipri Hora	-	-	+°
	Glyptothorax annandalei Hora	-	-	+°
	Glyptothorax horai Shaw & Shebbeare	-	-	+°
	Glyptothorax telchitta (Hamilton)	-	-	+°
	Laguna ribeiroi Hora	-	-	+°

FISH FAUNA OF RIHAND RESERVOIR (CONTD)

	Species	Project	Motwani	Hora
Family	ANGUILLIDAE			
	<u>Anguilla</u> <u>bengalensis</u> (Gray & Hardwicke)	+°	–	–
Family	BELONIDAE			
	<u>Xenentodon</u> <u>cancila</u> (Hamilton)	–	+°	–
Family	MUGILIDAE			
	<u>Rhinomugil</u> <u>corsula</u> (Hamilton)	+	+	–
Family	OPHIOCEPHALIDAE			
	<u>Channa</u> <u>marulius</u> (Hamilton)	+	+	–
	<u>Channa</u> <u>striatus</u> (Bloch)	–	+°	–
	<u>Channa</u> <u>gachua</u>	–	–	+°
Family	AMBASSIDAE			
	<u>Chanda</u> <u>nama</u> (Hamilton)	+	+	–
	<u>Chanda</u> <u>ranga</u> (Hamilton)	–	+°	–
Family	GOBIIDAE			
	<u>Glossogobius</u> <u>giuris</u> (Hamilton)	+	+	+
Family	MASTOCEMBELIDAE			
	<u>Mastocembelua</u> <u>armatus</u> (Lecepede)	+	+	+

\+ Recorded
+° New records

and 10 families. After the impoundment (1962), Motwani (1970) listed 44 species belonging to 29 genera and 12 families. The list of fish fauna compiled by the Coordinated Project has 17 species in common with that of Motwani and 7 with that of Hora. The following six are the new records registered by the Project :

1. Barilius barila (Hamilton)
2. Botia dayi (Hora)
3. Ompok pabda (Hamilton)
4. Heteropneustes fossilis (Bloch)
5. Gagata itchkeea (Sykes)
6. Anguilla bengalensis (Gray & Hardw)

15 EFFECT OF IMPOUNDMENT ON REPRODUCTION

15.1 Recruitment and breeding success

Studies on the recruitment and breeding success of Indian major carps were conducted in the Lotic sector by collecting the eggs and fry during the monsoon season. In 1973, only 500 eggs and 200 fry were collected. The composition of fry was represented by uneconomical species like Garra sp., Glossogobius giuris, Notopterus spp., Cirrhinus reba and Osteobrama cotio. Occurrence of a few larger ova (4.5 to 5.0 mm in diameter) and a few spent females of C. mrigala indicated stray breeding of major carps.

In 1974, 60,000 eggs were collected in seven days. The egg spurt appeared in bulk on 15-16 July only and continued in traces till 30 July. No eggs were collected afterwards. The quality of eggs collected on 16 July was good as the eggs on further rearing were found to contain C. mrigala (55.6%) followed by C. catla (7.6%) and L. calbasu (7.1%) (Table XV1).

In 1975, 81,000 eggs were collected from the major spurt on 16 July in the morning which continued till evening. Before the occurrence of this spurt congregation and sexual play of Catla was also observed in the evening of 15 July. The quality of eggs on rearing showed the dominance of C. catla (43.6%) followed by C. mrigala (38.5%), L. rohita (5.1%) and L. calbasu (5.1%). The fry and

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Motwani, M.P. (1970). Report on fish and fisheries of Rihand reservoir. Department of Fisheries, Uttar Pradesh, Lucknow.

Fingerlings collected from the marginal pockets of the reservoir also had *C. catla* (6.9%), followed by *C. mrigala* (6.5%) and *L. calbasu* (4.6%) (Table XV).

TABLE XV

Species composition of major carps in Rihand reservoir through rearing of eggs and Jaunpur drag net collection (1974-1977)

Year	Period of breeding	Total no. of eggs collected	REARING OF EGGS					JAUNPUR NET COLLECTION				
			C. catla	*C. mrigala*	*L. calbasu*	*L. rohita*	Others	*C. catla*	*C. mrigala*	*L. calbasu*	*L. rohita*	Othe
1974	15.7.74 to 20.7.74	60,000	7.6	55.6	7.1	2.7	27.0	-	-	-	-	-
1975	16.7.75	81,000	43.6	38.5	5.1	5.1	7.7	6.9	6.5	4.6	0.9	81.
1976	30.7.76	87,200	54.1	34.0	6.4	5.5	-	14.3	7.4	2.8	2.1	73.
1977	27.7.77	4,500	57.1	26.6	6.5	5.4	4.4	17.6	4.4	3.5	2.4	72.

Others - *C. reba*, *P. sarana*, *W. attu*, *R. corsula*, *N. notopterus* and *G. giuris*

In 1976, the availability of eggs was confined to a day only (30 July) yielding 87,200 eggs. Lotic sector and the catchment area of Rihand river had heavy rain in the afternoon of 29 July resulting in a heavy inflow of water. The egg spurt lasted for 8 hours and comprised *C. catla* (54.1%) and *C. mrigala* (34.0%). The quality of fry and fingerlings collected from the reservoir also showed a dominance of *C. catla* (14.3%) followed by *C. mrigala* (7.4%). It has also been observed from the occurrence of fry that in Rihand *L. calbasu* is the first to breed followed by *L. rohita*, *C. mrigala* and *C. catla*.

In 1977, only 4,500 eggs were collected in three hours on 27 July. The quality of eggs on their rearing showed higher percentage of *C. catla* (57.1%) followed by *C. mrigala* (26.6%). The qualitative analysis of fry and fingerlings from the reservoir also had *C. catla* (17.6%) and *C. mrigala* (4.4%). The trend of species composition observed this year fairly agreed with that of 1975 and 1976 (Table XV).

15.2 Influence of monsoon inflow on breeding

Studies on the effect of inflow on the breeding success of major carps have revealed that early monsoon inflow, especially in July, governs their breeding.

TABLE XVI

Rainfall, monsoon/annual inflow and water level in Rihand reservoir (1973-77)

Year	Rainfall (cm)	Monsoon inflow (m.a.ft.)			Annual inflow (m.a.ft.)	Reservoir water level in July (m)
		July	August	September		
1973	107.45	0.39	1.10	1.59	4.07	243.21
1974	140.89	1.09	1.04	0.22	2.65	247.04
1975	153.36	1.34	3.67	1.02	6.93	246.91
1976	95.60	1.03	1.47	0.74	4.81	257.75
1977	260.91	2.65	2.27	0.98	7.23	251.02

Low rainfall (107.45 cm) coupled with poor early monsoon inflow of water (0.39 m.a.ft.) in July in 1973 (Table XVI) was not sufficient enough for breeding migration of fish and hence major carp breeding probably failed or remained poor. Though the inflow improved in August and September, it was of no use. During the years 1974 to 1977, the inflow in July was high (1.09 to 2.65 m.a.ft.) and could thus ~~in~~ induce the fish to undertake breeding migration and hence successful breeding was observed. It also merits mention that though the rainfall was the poorest in 1976 (95.60 cm), the inflow in July (1.03 m.a.ft.) was high enough to help migration and breeding of fish.

15.3 Yearly variationsin egg collection site

It has also been observed that the egg collection site was never the same during the five seasons but varied from year to year according to reservoir water level. As the water level was the lowest in 1973 (243.21 m), the eggs were collected at a site nearer the confluence of the river with the Lotic sector. With the rise in water level from 1974 to 1977 the eggs were collected at sites which were upstream of the site in 1973.

16 COMMERCIAL FISHING

An exploratory survey of Rihand reservoir conducted in 1962 by the State Fisheries Department indicated that marketable fish was available in the reservoir. It then decided to start commercial fishing in 1963-64. Since no fishing villages or fishermen population existed along the periphery of the reservoir, the fishermen living along the banks of river Ganga in District Mirzapur (160 km from Rihand Dam) were encouraged by the State Department to come to Rihand for commercial fishing and a Fishermens' Cooperative Society known as Pant Sagar Matsyajivi Sahakari Samiti organised. The Society was also given necessary facilities such as provision of fishing boats, supply of nylon yarn for gill nets, etc, by the State Department. A system of inviting tenders for lifting the fish catch was introduced.

Commercial fishing is done for 9 months in a year excepting June to August which is treated as a closed season. During a greater part of the year, fishing is done in Lotic and Intermediate sectors. The fishermen very rarely exploit the Lentic sector. Of the fishing sites in Lotic, Intermediate and Lentic sectors, Pipra, Chargora, Adhaura, Bijpur, Mithini, Bichhia, Baraidand and Dongia nala on southern bank and Balleyari, Saipur, Kota, Mishra, Kuldumri, Belwadah, Sendur and Dam site on northern bank are the most important (Fig.19). The fishermen after fishing at one particular site for 4-5 days shift to the next site in rotation. Commercial fishing is thus done along the entire periphery of the reservoir, the Lotic and Intermediate sectors being exploited more intensively. The fish catch (Fig.20) from different sites is brought by a boat which is towed by the launch and landed at Kuldumri landing centre which is easily approachable by road from Rihand. After weighment at the landing centre, the fish is packed in ice and sent by the contractor's truck to Mughalsarai Railway Station from where it is sent to Howrah. The ice for packing is procured by the contractor either from Varanasi, Mughalsarai, Robertsganj or Chopan.

While the contractor or any party lifting the fish catch has to pay the cost of fish to the State Fisheries Department according to rates fixed for different categories of fish, the fishermen are paid fishing (labour) charges for their catch depending on the category of fish.

16 [illegible]

16.1 Fishing unit

Commercial fishing in Rihand reservoir is conducted by nylon surface gill nets and a country boat. The head rope of the gill net is ∠ synthetic material ∠of on which the webbing is directly hung with a hanging co-efficient of 0.5 to 0.7. The net is without a foot rope and has floats usually of dried pumpkins or empty tin containers. The nets have mesh bars ranging from 50 to 200 mm. The country boat is flat-bottomed, 7.3 m in length and 1.2 m in width. A fishing unit consists of a boat with 2-4 fishermen and 25 gill nets of different mesh bars. Each net on an average has a length of 30 m.

16.2 Yearly variations in fish yield

Taking 1971-72 as the base year, the annual fish yield progressively increased (Table XVII) from 1972-73 (184.13 t) to attain maximum in 1974-75 (328.82 t). The yield decreased from 1975-76 (160.75 t) to 1977-78 (83.49 t). In 1978-79 the fishing was done only for a month and therefore the yield was considerably low. Though the yield increased in 1979-80 (148.15 t), it was still below the level of the base year (152.40 t). However, it decreased further during 1980-81 (79.52 t) owing to poor fishing effort which was about half of the previous year.

16.3 Yield/ha

The yield/ha also progressively increased (Table XVII) from 5.05 kg (1971-72) to 10.91 kg (1974-75) and then decreased to 2.76 kg (1977-78). The yield/ha during 1979-80 (4.91 kg) is almost about the same as in the base year, but again decreased to 2.64 kg in 1980-81.

16.4 Fishing effort and its impact on yield

Taking 1972-73 as the base year (Table XVII), even the decreased fishing effort during 1973-74 (16.77%) yielded an increased catch of 31.77%. The increase in fishing effort during 1974-75 (95.76%) and 1975-76 (20.06%) improved the catch by 78.57% and 12.67% respectively (Fig. 21). Despite the increase in fishing effort in 1976-77 (26.87%), 1977-78 (14.84%), and 1979-80 ([illegible]) ∠ the fishery continuously declined as compared to the base year (1972-73). The lowest yield of 1978-79 was due to the fact that the fishing was conducted only for a month.

∠ and 1980-81 (79.52 t),

TABLE XVII

ANNUAL YIELD AND FISHING EFFORT IN RIHAND RESERVOIR (1971-72 TO 1980-81)

Years	Total yield (t)	Yield/ha (kg)	Number of nets	Number of 50 m units	Catch/ 50 m unit (kg)	Percentage increase/ decrease	
						Effort	Catch
1971-72	152.40	5.05	-	-	-	-	-
1972-73	184.13	6.11	1,26,597	75,285	2.44	-	-
1973-74	242.62	7.85	1,05,029	62,656	3.87	-16.77	+31.77
1974-75	328.82	10.91	2,45,626	1,47,375	2.23	+95.76	+78.57
1975-76	160.75	5.33	1,50,644	90,386	1.78	+20.06	+12.67
1976-77	68.23	2.26	1,39,442	95,513	0.71	+26.87	-62.97
1977-78	83.49	2.76	1,44,095	86,457	0.96	+14.84	-54.65
1978-79	24.87	-	34,249	20,549	1.21	-72.71	-86.48
1979-80	148.15	4.91	4,10,106	2,46,063	0.60	+226.84	-19.54
1980-81	79.52	2.64	2,25,449	1,35,269	0.58	+78.08	-56.81

16.5 Fish yield in relation to reservoir water level

The fish yield of Rihand reservoir appears to be affected by reservoir water level and shows an indirect relationship (Fig.22).

The yield was high in 1973-74 (242.62 t) and 1974-75 (328.82 t) when the water level was low (248.55 and 248.22 m respectively). The yields were comparable in 1971-72 (152.40t), 1972-73 (184.13 t) and 1975-76 (160.75 t) when the water levels were more or less of the same magnitude (261.59, 257.36 and 257.85 m respectively). Minor variations in the total yield during these years may be due to the variability in the intensity of fishing effort and abundance of fish stocks. Apart from fish abundance, the reservoir water level is also a factor, which is responsible for variations in fish yield. It is apparent from this relationship that since the reduced water level permits effective operation of gill nets, the catch is high and vice versa. During 1974-75, when the water levels were low, the fishermen also resorted to column setting of gill nets which resulted in particularly high catches during that year.

16.6 Catch structure

The commercial fishery of Rihand reservoir was dominated by *C. catla* which formed 84.2 to 99.1% in the total fishery from 1971-72 to 1980-81 (Table XVIII). The other species which contributed to the fishery included *C. mrigala*, *L. calbasu*, *L. rohita*, *L. bata*, *P. sarana*, *W. attu*, *S. silondia*, *Mystus* spp., *B. bagarius*, *N. chitala* and *N. notopterus* and *C. marulius*.

TABLE XVIII

Fish catch structure in Rihand reservoir (1971-72 to 1980-81)

Year	Percentage	
	C. catla	Others
1971-72	99.2	0.8
1972-73	98.8	1.2
1973-74	95.6	4.4
1974-75	99.1	0.9
1975-76	90.2	9.8
1976-77	87.1	12.9
1977-78	90.5	9.5
1978-79	-	-
1979-80	84.2	15.8
1980-81	73.1	26.9

16.7 Stock characteristics of C.catla

As seen from the catch (kg)/unit of effort (50 m length), it is evident that though the fishing effort was increased in 1974-75 from base year 1972-73, the catch/50 m unit remained the same in 1972-73 (2.44 kg) and 1974-75 (2.23 kg). This shows that the stock density of C.catla was not affected (Table XVII). Even with reduced fishing effort in 1975-76 and 1976-77, the catch/50 m unit continued to show a downward trend being 1.78 kg and 0.71 kg respectively. The fishing effort was abruptly raised in 1979-80 over that of base year (1972-73) but that also did not bring about any improvement in Catla fishery, the catch/unit effort index being very low (0.60). The fluctuations in the landings and low catch/unit effort index point to the poor abundance of the stocks and recruitment variability.

16.8 Selective fishing

Spot sampling of commercially operated gill nets has shown that the nets of larger mesh bars (150-170 mm) were operated more commonly by the fishermen. Due to this selective mode of fishing the catch of C.catla was the most dominant and represented only by higher size groups (900-1100 mm/14-25 kg).

An interesting observation was made in December 1975 when two different fishing parties, one using the nets of smaller mesh bars (100 mm and below) and the other that of larger mesh bars (140-180 mm) found that the larger-meshed nets predominatly landed C.catla (97.2%) while the smaller-meshed nets yielded the same in a much lower magnitude (35.6%) though with better catches of other species (Table XIX). As the fishermen are interested in better yields especially in terms of large-sized Catla which fetch

TABLE XIX

Catch composition of gill nets of different mesh bars

Species	Percentage (By weight)		Percentage (By number)	
	Small mesh	Large mesh	Small mesh	Large mesh
C. catla	35.6	97.2	11.1	91.1
C. mrigala	7.6	0.7	14.1	4.4
L. rohita	25.4	0.6	28.3	1.5
L. calbasu	2.4	0.1	5.1	1.5
W. attu	10.9	-	6.1	-
M. seenghala	2.5	-	3.0	-
S. silondia	7.6	-	15.1	-
B. bagarius	-	1.4	-	1.5
N. chitala	8.0	-	17.2	-

a higher price, they obviously prefer fishing with nets of larger mesh bars. Hence, the selective mode of fishing in Rihand for catching large-sized catla only.

16.9 Drag net fishing

In 1979-80, fishing with drag net was undertaken in the Lotic sector of the reservoir by the State Fisheries Department for the first time since the commencement of commercial exploitation in 1963-64. The operation was initiated on 24 October using a net of 441 m in length by a team of 13 fishermen. A comparison of monthly fish catch showed that while C. catla declined from 94.23% (September) to 72.48% (December), the percentages of C. mrigala, W. attu, S. silondia and N. chitala improved following the drag net operation (Table XX). The species like C. marulius, P. sarana and

TABLE XX

Catch composition (% by weight) in total landings through gill and drag net operations

Species	Gill net Sept.1979	Gill and drag nets October	November	December	Jan. 1980	Feb.
C. catla	94.23	96.94	76.76	72.477	79.998	84.66
L. rohita	0.60	0.63	0.77	0.187	0.293	0.30
C. mrigala	0.92	5.36	7.82	6.371	4.182	1.52
L. calbasu	0.27	0.44	0.34	0.525	0.145	0.02
P. sarana	-	-	-	0.091	0.036	0.08
W. attu	1.48	2.80	5.67	5.905	3.705	2.67
Mystus spp.	0.24	0.85	1.99	2.726	2.826	1.80
S.silondia	0.85	1.10	2.63	5.510	3.890	5.32
B. bagarius	0.98	1.03	0.06	0.113	0.184	0.03
N. chitala	0.42	0.77	3.24	5.602	3.943	3.14
N.notopterus	0.01	-	0.18	0.345	0.212	0.19
C. marulius	-	0.08	0.54	0.148	0.586	0.27

N. notopterus which were not encountered in the commercial catch occurred in drag net catches. This shows that with employment of additional fishing methods, the species composition in the total yield is also likely to improve.

17 EXPERIMENTAL FISHING

17.1 Work done by State Fisheries Department

Experimental fishing was conducted in the Intermediate sector, around Kuldumri fish landing centre, by the Gear unit of the State Fisheries Department from October 1973 to February 1974. The unit operated on an average 25-30 surface gill nets of different types and mesh bars (50 to 180 mm) every day for 24 hours. During the course of this fishing, a total of 1681.45 kg of fish was caught in which C. catla was the dominant species forming 52% of the catch. C. mrigala and L. calbasu, though poorly represented in the commercial catch, were also important contributing 15.10 and 10.08% respectively (Table XXI). It was further observed that among the nets of smaller mesh bars (50-90 mm), the catch/net/day of 60/trammel (0.75 kg) was the highest followed by that of 70/trammel (0.67 kg) and 60/trammel (0.63 kg). In the nets of larger mesh bars (130-180 mm), the catch/net/day of 130/ordinary (8.17 kg) was the highest followed by that of 170/trammel (1.67 kg) and 160/trammel (1.32 kg). The average catch/net/day was found to be 0.64 kg during the entire period of fishing (Table XXII).

17.2 Work done by the Project using State nets

Initially, the Project conducted experimental fishing in February-March 1975 using surface gill nets of the State Fisheries Department. 11 gill nets with mesh bars ranging from 15 to 180 mm were operated in the entire stretch of reservoir covering all the three sectors (Table XXIII). The span of 120 fishing hours yielded a catch of 42.997 kg. It is evident from this data that the bulk of the catch (32.835 kg) was landed in the Intermediate sector followed by Lotic (10.0 kg) and Lentic (0.162 kg). The catch was represented by C. catla followed by S. silondia, M. seenghala and N. chitala. Catfishes like C. garua and E. vacha, not seen in the commercial landings, were also available in the experimental catch (Table XXIII).

17.3 Work done by the Project nets

As per the work programme, multimeshed gill nets were to be operated for 4 days in each of the three sectors totalling to 12 days/month in the entire stretch of the reservoir but owing to certain difficulties and lack of facilities fishing could be done only for three months i.e. during April 1979, and March and July, 1980. Even during this period, TAE_E XXI

CATCH COMPOSITION OF EXPERIMENTAL GILL NETS USED BY GEAR UNIT OF STATE FISHERIES DEPARTMENT

Species	No.of specimens	Size range (mm)	Weight (kg)	Percentage (by weight)
C.catla	45	913-1065	874.50	52.00
L.rohita	8	395-940	31.40	1.87
C.mrigala	122	342-727	253.75	15.10
L.calbasu	64	350-600	169.60	10.08
P.sarana	10	247-452	4.95	0.30
W.attu	25	885-1415	165.90	9.87
S.silondia	111	200-840	101.45	6.03
M.seenghala	4	432-1215	18.50	1.10
M.aor	4	400-112[illegible]	13.60	0.81
E.vacha	4	240-329	0.65	0.04
R.rita	3	435-500	3.85	0.22
N.chitala	17	271-700	28.55	1.70
N.notopterus	118	281-508	14.75	0.88
Total			1681.45	100.00

TABLE XXII

NET-WISE CATCH OF EXPERIMENTAL GILL NETS USED BY GEAR UNIT (STATE FISHERIES)

Sl. No.	Particulars of net (Mesh bar in mm/ type)	Total Number of nets operated	Total catch (kg)	Catch/net/ day (kg)	
1.	50/Frame	483	223.75	0.47	
2.	50/Trammel	501	229.85	0.46	
3.	60/Frame	237	149.10	0.63	III
4.	60/Trammel	192	144.35	0.75	I
5.	70/Ordinary	223	21.60	0.09	
6.	70/Frame	125	7.70	0.06	
7.	70/Trammel	126	85.20	0.67	II
8.	80/Ordinary	190	10.90	0.06	
9.	80/Frame	123	11.45	0.08	
10.	80/Trammel	123	47.45	0.38	
11.	90/Ordinary	181	32.20	0.18	
12.	90/Frame	122	6.00	0.05	
13.	90/Trammel	124	33.90	0.27	
14.	130/Ordinary	3	24.50	8.17	I
15.	140/Ordinary	30	Nil	-	
16.	140/Ordinary	38	Nil	-	
17.	150/Ordinary	28	Nil	-	
18.	150/Trammel	25	Nil	-	
19.	160/Ordinary	95	73.00	0.77	
20.	160/Frame	43	45.50	1.05	
21.	160/Trammel	43	57.00	1.32	III
22.	165/Green	223	124.50	0.54	
23.	165/White	218	98.00	0.45	
24.	165/Red	112	38.00	0.34	
25.	165/Frame	52	Nil	-	
26.	165/Trammel	52	Nil	-	
27.	170/Ordinary	91	74.50	0.82	
28.	170/Frame	57	19.00	0.33	
29.	170/Trammel	49	82.00	1.67	II
30.	180/Trammel	56	42.00	0.75	
31.	180/Ordinary	17	Nil	-	
32.	180/Frame	14	Nil	-	
	Total		1681.45	Av. 0.64	

TABLE XXIII

EXPERIMENTAL FISHING WITH STATE GILL NETS (FEB. & MAR.'75) IN THREE SECTORS OF THE RESERVOIR

Mesh bar (mm)	LENTIC				INTERMEDIATE				LOTIC			
	Species	No.	TL (mm)	Wt. (kg)	Species	No.	TL(mm)	Wt. (kg)	Species	No.	TL	Wt. (kg)
15		Nil			O.bacaila	3	140-151	0.039		Nil		
					O.cotio	1	65	0.001				
25	O.bacaila	2	242-243	0.162	S.silondia	2	258-283	0.220		Nil		
					C.garua	2	230-295	0.220		Nil		
					E.vacha	2	243-250	0.180				
					R.corsula	1	268	0.175				
90		Nil				Nil			M.seenghala	1	1210	7.0
110		Nil			N.chitala	1	-	3.00	N.chitala	1	843	3.0
					S.silondia	1	1130	9.00				
160		Nil				Nil				Nil		
170		Nil				Nil				Nil		
180		Nil			C.catla	1	960	20.0		Nil		
Total				0.162				32.835				10.0
					Grand Total			42.997 kg				

the work had a severe set-back and against the proposed programme of fishing for 12 days in a month, the nets could be plied only for 3-8 days in each of the three months. Nets with smaller mesh-bars (20-90 mm) alone were used.

In April 1979, 44 nets were operated from 5.4.79 to 9.4.79 in the Intermediate sector of the reservoir. In 48 hours of operation, a total catch of 12.589 kg was obtained giving 0.005 kg/net/hr. In the total catch, S. silondia (68.93%) was the most dominant followed by C. garua (17.55%). The net of 80 mm bar contributed the highest catch (39.71%) followed by that of 40 mm (19.46%) and 45 mm (17.88%). In March 1980, 43 nets were again operated in the Intermediate sector from 26.3.80 to 29.3.80. In 36 hours of fishing, a total catch of 7.115 kg with 0.004 kg/net/hour was obtained. Among the species, S. silondia (35.62%) was the most important followed by P. sarana (11.30%), E. vacha (10.19%), L. calbasu (9.83%), C. reba (9.27%) and C. garua (8.78%). The net with 30 mm mesh bar gave the highest yield (39.49%) followed by that of 20 mm (16.59%) and 25 mm (15.05%) (Table XXIV).

Table XXIV

Species-wise and net-wise distribution of catches in experimental fishing in Rihand reservoir

Species	Catch (kg)		Net	Catch	
	April 1979	March 1980	(mm bar)	April 1979	March 1980
S. silondia	8.678	2.535	20	1.119	1.180
M. aor	-	0.125	25	1.070	1.070
C. garua	2.209	0.625	30	0.400	2.810
E. vacha	0.150	0.720	35	-	0.405
L. calbasu	-	0.700	40	2.450	0.300
C. mrigala	1.350	-	45	2.250	0.500
C. reba	0.050	0.660	50	0.300	0.850
P. sarana	-	0.805	80	5.000	-
O. bacaila	0.152	0.595			
N. chitala	-	0.125			
M. armatus	-	0.225			
	12.589	7.115		12.589	7.115

In July 1980, fishing was done both in the Lotic and Intermediate sectors (Table XXV). In 42 hours of fishing and operation of 35 nets in the Lotic sectors, a total catch of 88.3 kg was obtained giving 0.06 kg/net/hour. L. calbasu (52.83%) was the most dominant species followed by L. rohita (13.36%), W. attu (11.89%), S. silondia (8.87%) and C. mrigala (6.62%). The net of 60 mm bar contributed the highest catch (23.95%) followed by those of 80 mm (15.63%) and 90 mm (13.70%). In Intermediate sector, 60 hours of fishing with the operation of 75 nets landed 60.76 kg of fish which amounted to 0.013 kg/net/hour. The catch was represented by C. mrigala (28.31%) followed by L. calbasu (26.0%), L. rohita (16.13%) and S. silondia (14.97%). The contribution of 40 mm net (17.77%) was the highest followed by those of 45 mm (12.75%), 70 mm (11.85%) and 35 mm (11.35%).

TABLE XXV

Species-wise and net-wise distribution of catch of experimental fishing in Rihand reservoir

Species	Catch (kg) July 1980		Net (mm bar)	Catch (kg) July 1980	
	Lotic	Intermediate		Lotic	Intermediate
W. attu	10.500	-	20	1.140	3.315
S. silondia	7.835	9.090	25	1.640	1.250
M. seenghala	1.600	-	30	2.550	4.850
C. garua	1.560	2.630	35	0.250	6.900
E. vacha	-	4.175	40	3.925	10.795
R. rita	1.200	-	45	1.150	7.750
L. rohita	11.800	9.800	50	7.300	4.000
L. calbasu	46.650	15.800	55	9.050	4.450
C. mrigala	5.850	17.200	60	21.150	3.150
C. reba	1.140	0.770	65	6.850	-
P. sarana	-	0.250	70	2.250	7.200
O. bacaila	0.170	0.895	75	2.550	4.250
M. armatus	-	0.150	80	13.800	2.850
			85	2.600	-
			90	12.100	-
	88.305	60.760		88.305	60.760

A comparison of catch/net/hour in the Lotic and Intermediate sectors during July 1980 clearly indicated that fish abundance was more in the Lotic sector which may be attributed to their breeding migration into the flowing waters. The catch of 60 mm mesh bar was the highest (23.95%) followed by that of 80 mm (15.63%) in the Lotic sector while the nets of 40 and 45 mm were the most effective in Intermediate sector contributing 17.8 and 12.8% of the total catch respectively.

Based on the limited nature of experimental fishing, nothing can be said definitely about the dispersal of fish stocks in relation to time and space. Pooled data on experimental fishing (Table XXVI) have shown that *L. calbasu* (37.4%) was the most dominating species followed by *S. silondia* (16.7%), *C. mrigala* (14.5%), *L. rohita* (12.8%), *W. attu* (6.2%) *C. garua* (4.2%) and *E. vacha* (2.9%). While for *L. rohita* (450-700 mm) the effective mesh bar was 50-90 mm, for *L. calbasu* (250-600 mm) and *C. mrigala* (390-800 mm) the mesh bars ranging from 30 to 90 mm were found suitable. *S. silondia* (190-930 mm), *C. garua* (220-370 mm) and *E. vacha* (260-400 mm) were caught more commonly in mesh bars ranging from 20 to 80 mm.

18 FISHERY BIOLOGY

18.1 *Catla catla* (Ham)

18.1.1 Morpho-biological variations

Catla catla is described as monotypic species in ichthyological literature. Studies carried out at Rihand provided evidences regarding existence of three populations morphologically identifiable by short, medium and long pectoral fins. Day (1878) has described the pectoral fin of *Catla* to be extending to the ventral which is considered as equivalent to long pectoral in the present context. The pectoral which reaches only half-way to the ventral is described as short pectoral. The pectoral in between these sizes is defined as medium pectoral. For convenience sake, *C. catla* is referred as *C. catla* (P_L), *C. catla* (P_M) and *C. catla* (P_S) to represent populations marked by long, medium and short pectorals respectively (Fig. 23).

The above character is of considerable taxonomic importance and is a morphological index of distinct populations as borne out by the fact that *Catla* with long, medium and

TABLE XXVI

POOLED DATA OF EXPERIMENTAL FISHING (APRIL'79, MARCH'80 AND JULY'80) SHOWING OVERALL SPECIES COMPOSITION WITH SIZE OF FISH AND MESH BAR

Species	No. of specimens	Size of fish (mm)	Weight of fish (kg)	% (by weight)	Mesh bar range (mm)
L.rohita	7	450-690	21.600	12.8	50-90
L.calbasu	62	255-605	63.150	37.4	30-90
C.mrigala	22	385-805	24.400	14.5	30-80
C.reba	47	175-290	2.620	1.6	20-40
P.sarana	4	250-280	1.055	0.6	30-40
O.bacaila	24	205-270	1.812	1.1	20-40
W.attu	1	1210	10.500	6.2	60
M.seenghala	1	670	1.600	0.9	65
M.aor	1	310	0.125	0.1	20
S.silondia	68	185-930	28.138	16.7	20-60
C.garua	67	220-365	7.024	4.2	20-50
E.vacha	23	258-405	5.045	2.9	20-80
R.rita	3	350-450	1.200	0.7	30-50
N.chitala	1	256	0.125	0.1	35
M.armatus	2	445-450	0.375	0.2	20-25
Total			168.769		

short pectorals are sharply different from one another in respect of length-weight, girth and feeding habits.

Length-weight relationship :

$C.$ *catla* (P_L) : $\text{Log } W = -3.3894 + 2.5496 \log L$

or $2.82 \times 10^{-4} L^{2.5496}$

$C.$ *catla* (P_M) : $\text{Log } W = -4.8220 + 3.0336 \log L$

or $1.51 \times 10^{-5} L^{3.0336}$

$C.$ *catla* (P_S) : $\text{Log } W = -5.0712 + 3.1262 \log L$

or $8.48 \times 10^{-6} L^{3.1262}$

where W stands for weight in grams and L for length in millimeters (Fig. 24).

The three regression equations, when tested together for equality using F-test, were found to be highly significant at 1% level (F_{4}, 201 = 14.57). Similar test for equality indicated significance in populations between P_L and P_M in respect of regression coefficient at 5% level (F_{1}, 131 = 3.8); between P_L and P_S at 1% level (F_1, 105 = 7.1); and between P_M and P_S at 1% level (F_1, 167 = 35.3). This analysis confirms distinct identity of the three populations which could be ecological or genetical or both.

Length-girth relationship

An analysis of covariance of the regression functions relating to length (L) and girth (G) of the three populations, testing all series together for homogeneity, indicated a high degree of significance at 1% level (F_4, 199 = 24.5). Their intercept values were also found highly significant at 1% level (F1, 201 = 53.41). The intercept values between P_L and P_M, P_L and P_S and P_M and P_S were also highly significant confirming distinct genetical identity of populations. The regression functions relating to length (L) and girth (G) of the three populations are expressed by the following equations :

$C.$ *catla* (P_L) : $G = 44.2822 + 0.7376\,L$

$C.$ *catla* (P_M) : $G = -4.2332 + 0.8060\,L$

$C.$ *catla* (P_S) : $G = 21.6492 + 0.8058\,L$

where G stands for girth and L for length of the fish in millimeters.

Food composition :

A study of the gut contents (Fig.25) of the three populations showed that C. catla (P_L) subsists predominantly on crustaceans (72.6%) while the populations P_M and P_S, despite the occurrence of crustaceans (14.8 - 32.8%), exhibit a marked preference for Microcystis (49.1 - 79.4%). These observations clearly showed that Microcystis was preferred and consumed more commonly by Catla P_M and P_S. The difference in feeding was also reflected by the variation in gut length/fish length ratio which showed an average value of 1:16.7 in C. catla (P_L), 1:7.6 in C. catla (P_M) and 1:7.4 in C. catla (P_S).

Fish length/scale length relationship :

Scales collected from the three populations of C. catla were examined separately for studies on age and growth. The fish length/scale length relationships were determined statistically and their regression equations are given below :

C. catla (P_L) : $S = 1.13 + 0.025\ L$ ($r = 0.99$)

C. catla (P_M) : $S = -5.48 + 0.032\ L$ ($r = 0.97$)

C. catla (P_S) : $S = -11.01 + 0.038\ L$ ($r = 0.99$)

where S = scale length (mm) and L = fish length (mm)

Lengths at ages :

The intermediate fish lengths of the three populations were back-calculated ascertaining five age groups from scale annuli (Table XXVII).

TABLE XXVII

Length-at-ages of the three populations of Catla catla

Age (Year)	Back-calculated lengths (mm)		
	P_L	P_M	P_S
I	450*	450 *	390*
II	635	635	573
III	787	789	728
IV	906	888	830
V	966	974	915

*Length ascertained by extrapolation of growth curve

It is evident from the above data that of the three *Catla* populations, *Catla* (P_L) and (P_M) are fast growing while *Catla* (P_S) is the slowest (Fig. 26). Although *Catla* (P_S) is the slowest among the three, its growth appears to be faster than *C. catla* from river Jamuna (Fig.26) estimated to be 295, 514, 716, 823 and 917 mm respectively in the life span of I to V years respectively (Natarajan and Jhingran, 1963).

Weights at ages and annual growth :

Using the length-weight relationships of the three populations, the weights-at-ages were also calculated. Based on these weights the annual growth between successive age groups was determined (Table XXVIII).

TABLE XXVIII

Weights-at-ages and annual growth of *Catla* populations

Age (yr)	Weights-at-ages (g)			Annual growth(%)		
	P_L	P_M	P_S	P_L	P_M	P_S
I	2372	1686	1069	141	186	233
II	5710	4816	3556	73	92	112
III	9868	9247	7521	43	43	50
IV	14130	13220	11320	18	33	36
V	16630	17540	15370			

The comparison of weights-at-ages has further shown that growth in terms of weight was also more in case of *Catla* (P_L) and (P_M) but less in *Catla* (P_S) thereby fully agreeing with the growth trend denoted by length.

A careful examination of length-weight relationship (Fig.24) has shown that while this growth trend in weight of the three populations is exhibited by the fish in the size range of 400-800 mm only, *Catla* (P_S) and *Catla* (P_M) overtake *Catla* (P_L) in growth at 800 and 900 mm respectively. However, further analysis of data for annual growth rate of fish gave interesting results. Going by the annual growth rate, *Catla* (P_S) was found to have an edge over that of *Catla* (P_L)

Natarajan, A.V. and A.G. Jhingran (1963). *Proc. nat. Inst. Sci. India* (B), 29(3) : 326-55 and (P_M). It is therefore inferred that while Catla (P_L) and (P_M) grow faster in length than their weights, Catla (P_S) grows faster in weight than its length (Fig.27). This variation in growth in length and weight of the populations was also indicated by the dissimilarities in girth/fish length ratio and also from the regression coefficients of length-weight equation. The girth/fish length ratio was maximum for Catla (P_S) indicating that the fish has more girth on account of its greater annual growth by weight only. The regression coefficient of 3.13 in Catla (P_S), being more than 3.0, also supports the conclusion that the fish weight increases faster than fish length. The regression coefficients of Catla (P_L) and (P_M) being 2.55 and 3.03 demonstrate that in these populations the linear growth is taking place at a greater rate than growth in weight.

von Bertalanffy's growth fit :

von Bertalanffy's growth equation was also utilised to derive the asymptotic length (l_∞) and growth parameters of the three populations.

The following are the derivations of the growth equation :

$$\text{C. catla } (P_L) : \; l_t = 1106 \left\{ 1 - e^{-0.41(t + 0.07)} \right\}$$

$$\text{C. catla } (P_M) : \; l_t = 1180 \left\{ 1 - e^{-0.32(t + 0.41)} \right\}$$

$$\text{C. catla } (P_S) : \; l_t = 1120 \left\{ 1 - e^{-0.33(t + 0.10)} \right\}$$

The lengths-at-ages calculated from the above growth equations also agreed with the lengths back-calculated from scale method (Table XXIX).

TABLE XXIX

Lengths-at-ages of Catla populations derived from growth equation

Age (Yr)	von Bertalanffy's fit (mm)		
	P_L	P_M	P_S
I	393	429	341
II	632	634	560
III	792	784	717
IV	898	892	831
V	968	971	912

18.1.2 Ecological populations

The three populations of C. catla reported from Rihand have been considered here only as ecological populations for the present since each of these populations has a specific 'role' corresponding to a 'niche' in the eco-system. Establishment of a separate taxon in the rank of sub-species may be examined if further observations in different ecotopes warrant such an measure. Ecological studies in Rihand have shown that it is a multifaceted eco-system which acts as a 'biological filter' to project three ecological populations in different sectors of the reservoirs according to the availability of their food niches. Thus the zooplanktophagie population of C. catla (P_L) appears to dominate the Lotic and Intermediate sectors where zoo-plankton availability is comparatively more while C. catla (P_M and P_S) dominate the Lentic followed by the Intermediate sector where phytoplankton is abundant.

18.1.3 Role of Catla (P_M and P_S) in Microcystis utilization

Microcystis dominates the plankton population of many Indian reservoirs, especially those in peninsular India. Studies under the All India Coordinated Research Project have shown the abundance of Microcystis in Getalsud reservoir (Bihar), Nagarjunasagar (Andhra Pradesh) and Bhavanisagar (Tamil Nadu), besides Rihand. In addition, Microcystis also dominates the plankton of ponds and tanks in several areas. No Microcystis feeding fish is known in India. In these circumstances, the two Catla populations of Rihand with medium (P_M) and short (P_S) pectorals have a significant role in the control and utilisation of Microcystis and thus in the development of pond and reservoir fisheries in India.

18.2 Catla x rohu hybrid

Taxonomic characters

Catla x rohu hybrid has a general appearance of C. catla having a conspicuously smaller head than catla but deeper body than rohu. The contour of the mouth is more akin to that of rohu though its position is terminal with its lips entire and without barbels. In morphometric ratios, the hybrid resembles catla in respect of length of body/girth of body and length of head/diameter of the eye. It resembles rohu in respect of length of body/length of head. The hybrid displays intermediate range in respect of length of body/ depth of body ratio. Meristic counts in respect of dorsal and pectoral fin rays have an intermediate range (Table XXX).

TABLE XXX

Taxonomic characters of catla x rohu hybrid of Rihand reservoir in comparison to its parent species

Characters	Catla	Rohu	Rihand hybrid
Length of fish/ Depth of body	3.2	4.0	3.4-3.5
Length of fish/ Length of head	3.8	4.5	4.1-4.5
Length of fish/ Girth of body	1.3	1.7	1.3-1.4
Length of head/ Interorbital space	2.0	1.8	1.6-2.0
Length of head/ Height of head	1.1	1.4	0.8-1.8
Length of head/ Diameter of eye	8.2	7.1	8.0-9.6
Dorsal fin rays	19	15	17-19
Pectoral fin rays	21	15	17-19
Anal fin rays	9	9	7-8
Position of mouth	Upturned	Inferior	Terminal
Nature of lips	Not fringed	Fringed	Not fringed
Number of barbels	No barbels	One pair	No barbels

Feeding habits

In reservoir environment the hybrid is detritophytoplanktophagic displaying proneness to a much a wider spectrum of food than encountered in ponds where the hybrid is known to take detritus, decaying vegetation, mud and sand. The gut analysis of hybrid under reservoir environment in Rihand shows the presence of detritus (45.0%), sand and mud (35.0%), Ceratium (18.7%) and

Keratella (1.3%). The percentage composition of Ceratium goes upto 40% in the gut contents in February when there is a minor bloom of this phytoplankter indicating a preference for this phytoplankter. The proneness of the hybrid to utilise Ceratium merits mention in that it is likely to prove very successful in Ceratium dominated reservoirs. The fish length/gut length ratio is 1:15 in the hybrid as against 1 : 7 in catla which shows its active leaning towards detritus and phytoplankton.

Age and growth :

The scales of catla x rohu hybrid were found suitable for age determination. The intermediate lengths at ages, as back-calculated from scale rings, of the hybrid and catla from Rihand reservoir are given in Table XXXI.

TABLE XXXI

Back calculated lengths-at-ages of catla x rohu hybrid and C. catla

Age	Catla x rohu hybrid		C. catla*	
	Length range (mm)	Average length (mm)	Length range (mm)	Average Length (mm)
II	420-470	434	372-520	466
III	542-628	578	598-720	669
IV	620-707	637	745-840	789
V	734-836	795	813-897	859
VI	904	904	-	-

* Representing mixed population

The following are the derivations for catla x rohu hybrid and catla for von Bertalenffy's growth equation :

Catla x rohu hybrid : $lt = 1026\ 1-e^{-0.27(t+0.02)}$

C. catla : $lt = 1273\ 1-e^{-0.25(t+0.04)}$

The asymptotic length ($l\infty$) of catla x rohu hybrid is below the level of catla by 247 mm. The lengths at ages of catla and catla x rohu hybrid calculated from von Bertalenffy's growth equation is presented in Table XXXII.

TABLE XXXII

von Bertalenffy's growth fit

Age	I	II	III	IV	V	VI
Catla	292	509	678	810	912	992
Catla x rohu hybrid	243	434	575	682	763	825

The above table brings out the fact that the growth rate of the hybrid compares favourably with that of catla.

The ovary of female hybrid was found to be in stage III (February) with developing eggs. It is likely that hybrids mature and breed early, perhaps in the first freshets of the monsoon.

18.3 Other species

The gut/stomach contents of another twelve species of fish available in the reservoir were also analysed. The size range of different species examined and their food composition are given in Table XXXIII.

TABLE XXXIII

Gut/stomach contents(%) of commercially important species of Rihand

Species	Size of fish (mm)	Sand/ mud	Organic detritus	Plant matter	Algae	Fish	Insect	Prawn	Shrimp	Mollusc
L. rohita	660	90.00	7.00	-	3.00	-	-	-	-	-
L.calbasu	360-600	31.75	60.00	-	8.25	-	-	-	-	-
C.mrigala	520-650	62.64	22.49	0.80	14.07	-	-	-	-	-
P.sarana	295-319	-	-	70.00	-	-	30.00	-	-	-
R.corsula	25-268	100.00	-	-	-	-	-	-	-	-
M.seenghala	1210	-	-	-	-	75.00	25.00	-	-	-
S.silondia	260-1130	-	23.40	-	-	40.60	36.00	-	-	-
W. attu	650-1160	37.50	-	-	-	62.50	-	-	-	-
C. garua	295-359	-	-	-	-	25.00	75.00	-	-	-
E. vacha	230-300	-	-	-	-	100.00	-	-	-	-
N.chitala	225-840	2.20	0.60	18.80	-	73.20	2.10	2.50	-	0.60
N. notopterus	275-375	2.50	9.80	27.50	3.45	3.65	23.10	-	30.00	-

The fecundity of the following species was estimated as :

Species	Size of fish(mm)	Number of eggs
C. catla *	1010-1112	36,26,000 - 47,92,000
L. rohita	635-665	5,97,567 - 17,28,000
L. calbasu	510-540	2,19,600 - 3,40,000
C. mrigala	580-680	1,86,878 - 4,98,578
N. chitala	645	1,253

18.4 Trash fish

The trash fishes collected from Lotic sector were examined for their food and maturity. The data on size of fish examined, food and maturity of 13 such species are shown in Table XXXIV. Most of the species were found to feed on insects and zooplankton.

TABLE XXXIV

Food and maturity of trash fish

S.N.	Species	Size range (mm)	Food	Maturity
1.	C. atpar	30-57	Insects & algae	-
2.	C. laubuca	26-56	Insects & zooplankton	July-Aug.
3.	O. bacaila	25-243	"	March
4.	B. bendelisis	39-43	Insects	-
5.	B. barila	20-50	Insects & zooplankton	-
6.	E. danrica	40-60	Algae & diatoms	-
7.	R. daniconius	45-65	Algae & insects	-
8.	A. mola	25-70	Algae	July-Aug.
9.	P. sophore	25-59	Algae & diatoms	-
10.	C. reba	30-55	"	-
11.	O. cotio	20-75	Insects & zooplankton	Dec. to Feb., April, July & Aug.
12.	C. latius latius	40-67	Algae & diatoms	-
13.	G. giuris	12-60	Insects & zooplankton	-
14.	W. attu	33-40	Insects	-
15.	N. notopterus	30-65	Insects & zooplankton	-
16.	N. chitala	140-95	"	-
17.	C. marulius	100-160	Insects	-

* Irrespective of ecological populations

18.5 Fin clipping

During October/November 1973 and March 1974, fins of 1120 fingerlings of major carps as per details given below were clipped and the fingerlings released in the reservoir for direct observations on growth.

Species	No.of fingerlings	Size range(mm)
C. catla	875	62-325
L. rohita	131	76-238
L. calbasu	21	80-215
C. mrigala	93	70-142

However, no recoveries were made and hence no conclusions could be drawn.

19 STOCK STRENGTHENING OF MAJOR CARPS

With a view to improve and strengthen the stocks of Indian major carps, the reservoir was stocked from 1963-64 to 1971-72 at a sufficiently high rate which worked out to about 25 fingerlings/ha but the stocking of the fingerlings/ha was of a very low order from 1972-73 to 1975-76 being 3 in 1972-73, 2 in 1973-74, less than 1 in 1974-75 and 3 in 1975-76.

20 ACKNOWLEDGEMENTS

The Project Coordinator, AICRP on the Ecology and Fisheries of Freshwater Reservoirs acknowledges with deep sense of gratitude the help and cooperation received from the ~~Department of Fisheries, Government of Uttar~~ Pradesh without which the present studies would not have been possible. Thanks are also due to the Executive Engineer (Irrigation), Rihand Dam for providing necessary data on meteorology, morphometry and physical features of the reservoir. The assistance received from the Executive Engineer, Uttar Pradesh Electricity Board, Rihand Dam is also thankfully acknowledged.

The work programme of the Project was drawn and finalised in consultation with the scientists and State Directors of Fisheries who participated in the various workshops. Thanks are also due to them all.

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22 SUMMARY

—— Rihand reservoir, formed with the impounding of Rihand river at Pipri (District Mirzapur, Uttar Pradesh), in 1962 is a hydel project having an average water area $\left(\frac{FRL + DSL}{2}\right)$ of 30,148 ha.

—— Average maximum air temperature at Rihand ranged from 26°.7C (January) to 45°.8 C (June) and the minimum from 6°.3 C (January) to 25°.6 C (May); total yearly rainfall from 107.45 to 260.91 cm; average wind velocity from 1.06 to 1.98 km/hr and, yearly average water level from 248.22 m (1974-75) to 258.43 m (1976-77).

—— Yearly water inflow in the reservoir varied from 2.650 m.a.ft. (1974-75) to 7.232 m.a.ft. (1977-78). The poor inflow in 1974-75 is the lowest recorded so far since the construction of the reservoir; the average water capacity varied from 3.05 m.a.ft. (1974-75) to 5.53 m.a.ft. (1975-76); and, the water outflow from the reservoir fluctuated between 25,50,217. cusecs (1975-76) and 73,91,124. cusecs (1976-77).

—— Loss of water through evaporation was maximum in August-September (0.054 m.a.ft.) and minimum in December (0.010 m.a.ft.).

—— Reservoir basin soil has medium organic carbon (0.08-1.13%); but poor available nitrogen (15.5-30.5 mg/100 g) and available phosphorus (1.1-2.3 mg/100 g). The nutrient status of soil is higher during post-monsoon than pre-monsoon period. Clay content (40-75%) is quite high in the reservoir and increases considerably after rains.

—— Water quality of the reservoir is good in respect of PO_4-P (0.079 ppm) but medium in NO_3-N (0.383 ppm). Total alkalinity (43.87 ppm), total hardness (15.7 ppm) and specific conductivity (92.24 micro/mhos/cm) are below average and the reservoir is therefore categorised as low productive. Though the reservoir shows strong thermal stratification (May), chemical stratification (June) is weak and near

uniform. The Lotic sector is comparatively chemically rich and the nutrient status of the water rather high during summer.

——— Both thermal and biochemical stratification of the reservoir get broken in July by the monsoon inflow. In years marked by low rainfall the thermal and chemical homogenisation is caused by convection currents as evidenced in November/December. A high oxygen content at the bottom (3.4 ppm and above) shows the absence of decomposing organic matter and poor biota.

——— Low rate of organic production confirms the chemical deductions on productivity. Low values of primary production (gross 387.04 and net 161.44 mg $C/m^2/day$) are attributed as much to high clay turbidity of water as to low level of nutrients.

——— Phytoplankton is mainly contributed by surface alga, Microcystis. Zooplankton is represented by copepods, cladocerans and rotifers. The phytoplankton population of the reservoir was the highest in 1976-77 and lowest in 1973-74 and seems to be regulated by free CO_2 content of inflowing water during monsoons. Sectoral distribution of planktonic groups was noted, phytoplankton being important in Lentic, phyto-zooplankton in Intermediate and zooplankton in the Lotic sector. Plankton concentration was higher along the northern bank of the reservoir owing to its favourable topography.

——— Benthic biota is very poor and is represented mainly by diptaran larvae (Chaoborus and Chironomus) and oligochaetes. During monsoon, benthos predominates in Intermediate and Lentic sectors while it dominates in the Lotic sector during periods of low turbulence.

——— Periphyton is scarce during monsoon owing to water turbulence but appears during postmonsoon months, when the reservoir is calm. It is mainly represented by Oscillatoria and its yearly abundance parallels that of plankton.

—— Aquatic plants do not occur due to cyclic sharp fluctuations in water level resulting in exposure of marginal areas.

—— Survey of fish fauna shows the presence of 44 species belonging to 33 genera and 13 families in the reservoir. Six of these species are new records.

—— Major carps spawn during monsoons in the Lotic sector but their breeding success largely depends on the monsoon inflow during July. Limited spawning habitat and competition between species of major carps for spawning are factors contributing to uni-species dominance by C. catla in the reservoir and occurrence of catla x rohu hybrids.

—— Fishery of the reservoir progressively improved from 1972-73 (6.11 kg/ha) to 1974-75 (10.91 kg/ha) following increased fishing effort. However, despite the highest fishing effort in 1979-80 the landings were poor (4.9 kg/ha). This decline was due to the dominance of the fishery by a single species viz. C. catla and failure of its breeding in earlier years and restriction of catch to a single age group.

—— Catla is the most dominant species in the reservoir and is represented by higher size groups due to selective mode of commercial fishing with gill nets of larger mesh bars (150-170 mm). The diversification of mesh bars and resultant reduction in large mesh bars are among factors that led to decrease in the percentage composition of C. catla from 99.2% (1971-72) to 84.2% (1979-80).

—— Experimental fishing conducted by the U.P. State Fisheries Department has shown poor stock strengths of L. rohita, L. calbasu and C. mrigala as compared to that of C. catla. This observation is also supported by poor recruitment of the first three species.

—— The unispecies fishery of C. catla comprised three ecological populations which are identified by the length of pectoral fin. Of these populations, Catla with short

(P_S) and medium (P_M) pectoral show apparent preferences to Microcystis while long pectoral (P_L) for zooplankton. Suitability of Catla (P_M) and (P_S) for stocking reservoirs dominated by Microcystis is indicated.

—— Biological studies on catla x rohu hybrids reveal their preference for Ceratium and faster growth than L. rohita and their importance in stocking Ceratium-dominated reservoirs is self-evident.

—— Stocking of the reservoir by the State Fisheries Department during the period 1972-73 to 1975-76 was of a considerably low order (1-3 fingerlings/ha) and such attempts are not likely to yield any results.

22 RECOMMENDATIONS

(i) Taking the yearly fluctuations in yield which is largely made of C. catla to the extent of 87-99% and catch unit effort index into consideration, it is obvious that the stock abundance in the reservoir is subject to considerable recruitment variability. Recruitment in respect of mrigal, rohu and calbasu are poor and this is reflected in their poor catches in experimental trials using smaller mesh bars. Breeding and recruitment success in Catla depend on monsoon inflow, especially in July and recruitment was poor in 1972 and 1973 when there was poor water inflow in that month. Since the catch is made of a single species and a single age group, recruitment failure is reflected in yield failure markedly in certain years. Stocking support for strengthening Catla stocks is therefore essential.

(ii) Abundance of periphyton and other benthic forms favour stocking of L. rohita, L. calbasu and C. mrigala and C. carpio. However, these may be only moderately stocked since benthos and periphyton occur only in moderate scale in the reservoir.

Primary production studies indicate that the reservoir is capable of yielding a production of 40 kg/ha (1200 t/yr). To realise this, it is recommended that stock diversification measures be taken up to obtain higher yields. As such and in the context of ecological considerations, stocking of L. rohita, L. calbasu and C. mrigala is recommended.

(iii) Studies on breeding and recruitment have shown that the recruitment of C. mrigala and L. calbasu is moderate while that of L. rohita almost negligible. It is therefore recommended that stock building of these species may be taken up in a planned manner on a regular basis with large-sized fingerlings (150 mm-200 mm) to escape predation by W. attu and S. silondia which are abundant in the reservoir.

(iv) Though species composition on stocking is not available but stocking at 25 fingerlings/ha during 1963-64 to 1971-72 seems to have had its impact on yield. However, low stocking at 1-3 fingerlings/ha during 1972-73 to 1975-76 has resulted in poor yields. Stocking at 50 fingerlings/ha in the ratio of 2 Catla : 3 L. rohita : 1 C. mrigala : 2 L. calbasu is recommended to realise optimum yields from the reservoir.

(v) Fishing effort in terms of absolute annual fishing units during 1972-73 to 1979-80 varied from 75,285 units (each unit of 50 m net length) to 246,063 units, of which the highest yield of 328 tonnes was obtained with an effort of 147,375 units (50 m net length). It is recommended that the effort be maintained at 150,000 units (50 m net length) for the present if Catla continues to be the dominant species in the catch and the size range of catch remains unaltered. The effort needs to be modified in qualitative (mesh) and quantitative terms if management is altered to the multi-species system.

(vi) Fishing effort, as at present employed, is concentrated on fishing large-sized Catla only. Since Catla breeds in the III year when it is about 550-650 mm/3.5-5.7 kg in weight and as its growth rate declines from IV year onwards when it attains a length and weight of 725-800 mm/8-10 kg, catching large-sized Catla weighing 15-25 kg is not sound in biological terms. Depth-related buoyancy factors governing size at capture preclude adoption of such a rational policy. Till an effective gear is developed or the existing gears improved that takes all size groups relevant to reservoirs, Central Institute of Fisheries Technology may provide expertise in this regard.

(vii) Experimental fishing has shown that S. silondia and W. attu have a potential of fishery of some importance in the reservoir. It is suggested that long line operations on a commercial scale be undertaken to selectively remove the large-sized predators and thus augment the total yield. This will also ensure better survival for carp young ones. Liberalised fishing without closed season using long lines is recommended for cat-fishes.

(viii) Based on morphological, morphometric and anatomical variations, the Catla stock of Rihand reservoir has been shown to comprise of three ecological populations which show differences in their food preferences and growth characteristics. Two of these viz. Catla with medium and short pectorals

(P_M and P_S) prefer <u>Microcystis</u> which is a difficult-to-digest food and not utilised by major carps in general. Since <u>Catla</u> is not only a highly priced fish but also the fastest growing Indian major carp, it is suggested that <u>Catla</u> (P_M and P_S) are induced-bred and the seed utilised for stocking <u>Microcystis</u> dominated reservoirs and ponds and tanks having permanent blooms for utilization and control of <u>Microcystis</u> and augmentation of fish production.

(ix) Commercial collection of carp eggs from the Lotic sector is undertaken by the State Fisheries Department. These may be reared and stocked in the reservoir to augment stock strengths of economic carps. The State Department may develop necessary infra-structural facilities such as an indoor hatchery and a seed farm as part of reservoir management complex for fishery development.

(x) Limited breeding grounds in the Lotic sector result in production of catla x rohu hybrids which have been found to grow faster than the parent rohu. Since the hybrid shows marked preference for <u>Ceratium</u> it is recommended that it be utilised for <u>Ceratium</u>-dominated reservoirs as well as ponds and tanks under culture. So far no other species is known to show such a marked preference for this plankter.

(xi) The effluents of Kanoria Chemicals Pvt.Ltd., Renukoot are characterised by high chloride and free chloride content which are highly toxic to fish and fish food organisms. Absence of planktonic food and fish mortality have been recorded. It is recommended that the management be directed to discharge the effluents after proper treatment so that fish life and fish food organisms in the reservoir is not affected.

(xii) As <u>Microcystis</u> blooms predominate in the Lentic sector it is suggested that cage culture of silver carp and <u>Catla</u> (P_M and P_S) may be undertaken on an experimental basis to assess its commercial possibilities.

(xiii)The reservoir is marked by high level of turbidity reflecting poor soil conservation measures in the catchment. This needs to be corrected.

(xiv) The Fishermen Cooperative Society should also function as a marketing society so that the fishermen get a better rate of emolument for their effort. In addition, the Government may also scale down the royalty rates so that the society is in a viable position to pay better wages to the fishermen. The State Fisheries Department may in turn spend a part of the royalty for developmental measures like stocking.

(xv) The Fisheries Department must have uninhibited freedom to develop the reservoir and the fisheries revenue from the reservoir need not be shared with Uttar Pradesh State Electricity Board. However, a separate board may be constituted where the hydel authorities and Fisheries Department are represented with the Director of State Fisheries as Chairman so that the hydel authorities may be kept informed of the developmental activities. It would also be possible for the Board to accommodate the view points of the two departments for mutual benefit of fisheries development and hydel generation.

(xvi) The development of reservoir fisheries calls for regular monitoring of yield and effort data. It is recommended that species-wise yield, size and weight composition of various species constituting the catch and detailed effort pattern is regularly recorded by the State Fisheries Department.

(xvii) The Fishermen Cooperative Society should also function as a marketing society so that the fishermen get a better rate of emolument for their effort. In addition, the Government may also scale down the royalty rates so that the society is in a viable position to pay better wages to the fishermen. The State Fisheries Department may in turn spend a part of the royalty for developmental measures like stocking.

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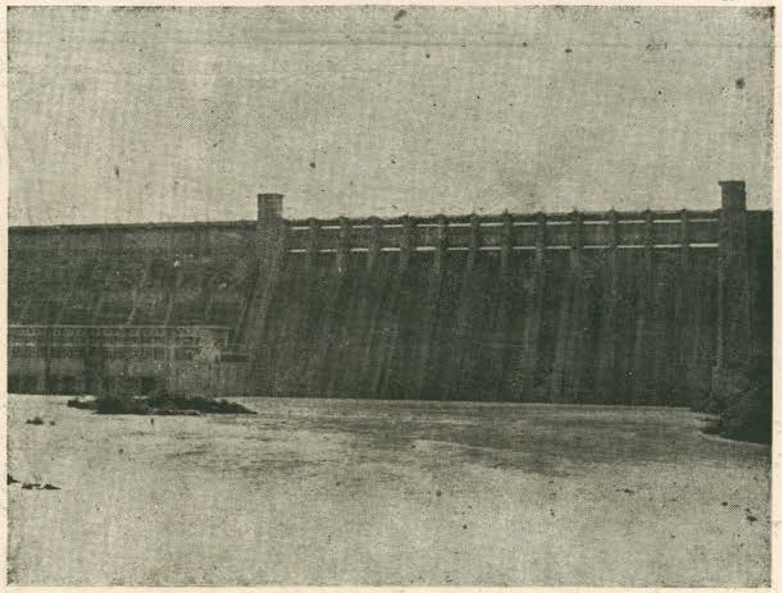


Fig. 1 A view of Rihand Dam

Fig. 2 Office and laboratory of the all India Co-ordinated Research Project, Rihand Sub-centre

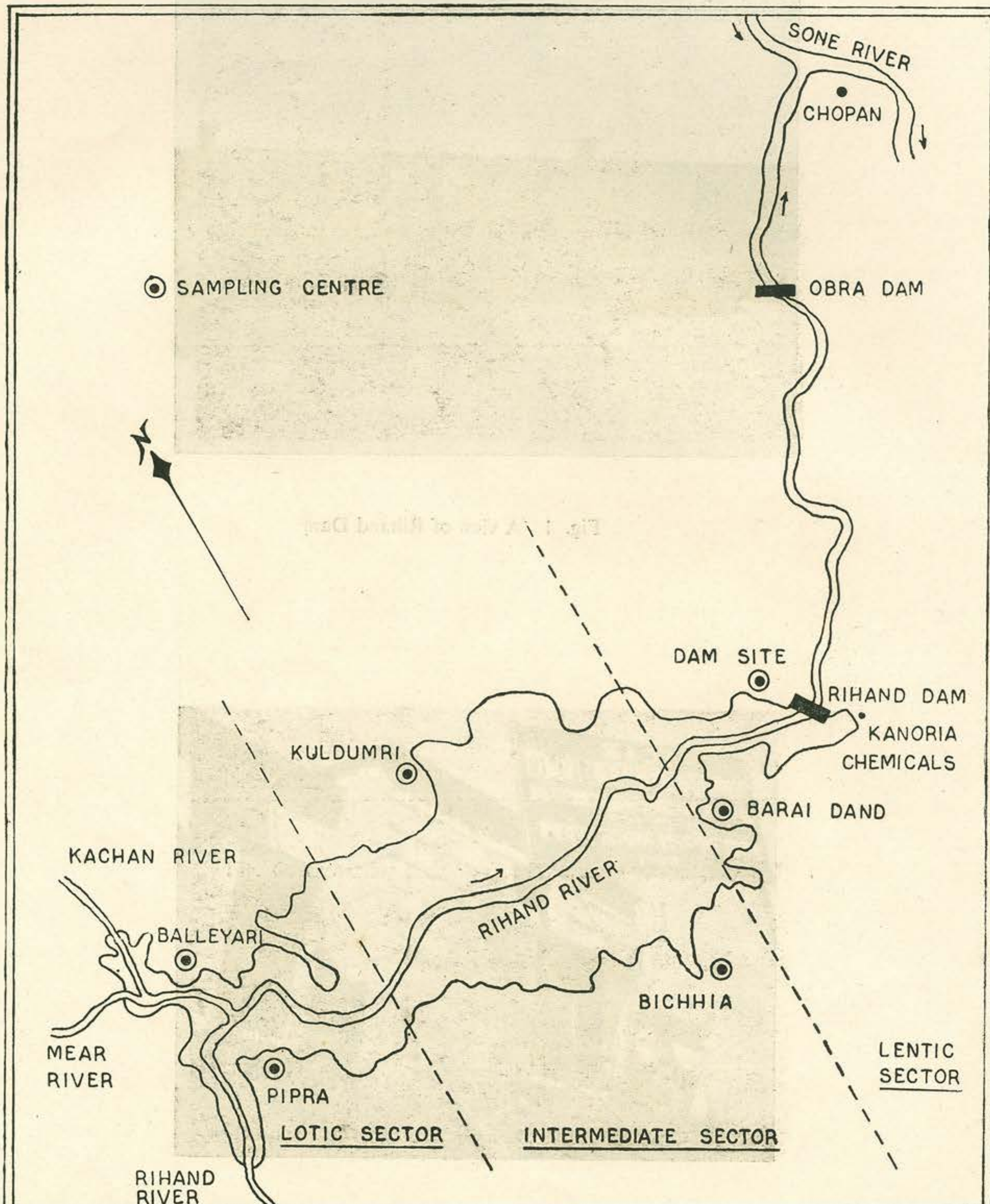


Fig. 3 Rihand reservoir zonal demarcations and sampling centres

Fig. 4 Lotic sector with clayey bed

Fig. 5 Lentic sector with steep banks covered with forest

Fig. 6 Operating Secchi's disc for water transparency

< Fig. 7 Collecting water samples with Von Dorn's Sampler

Fig. 8 Incubation of light and dark bottles for primary production >

< Fig. 9 Making vertical hauls with plankton net

Fig. 10 Centrifugation of plankton samples >

Fig. 11 Ekman's dredge operation for bottom-biota

Fig. 12 Sieving the bottom samples through No. 40 brass sieve

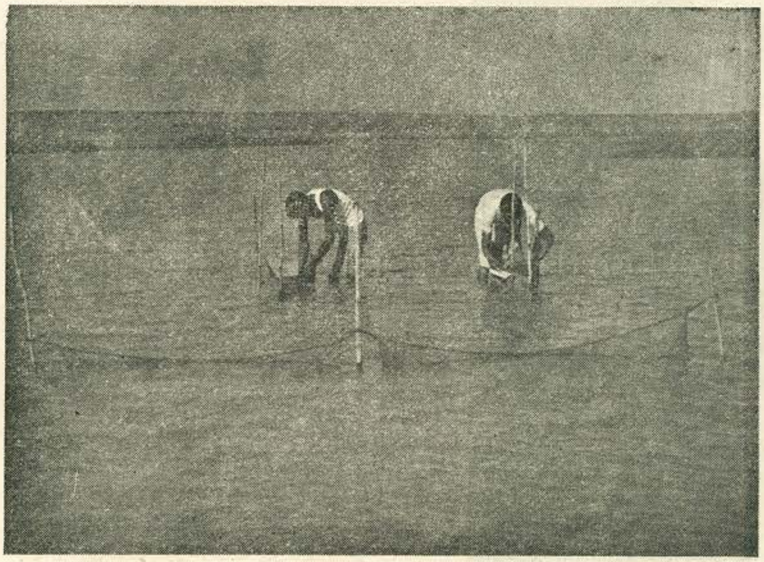


Fig. 13 Operation of spawn nets in Lotic sector for recruitment studies

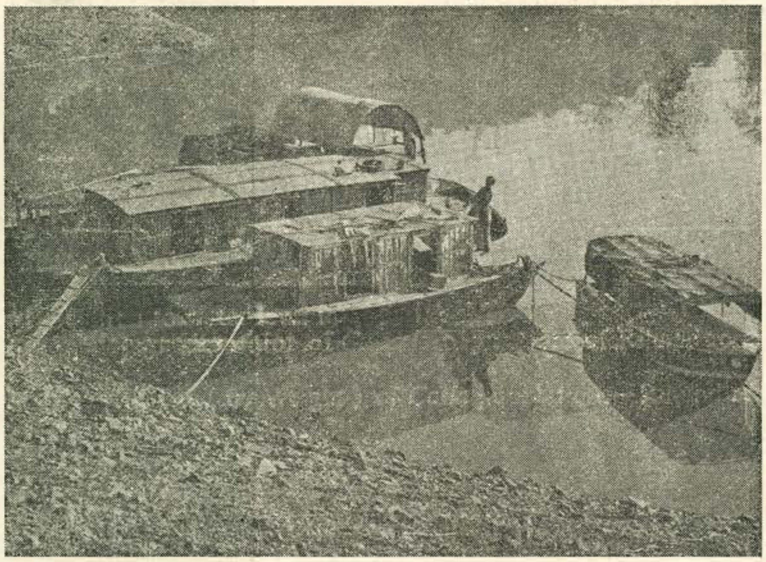


Fig. 14 House-boats and motor-launches for camping and transport of fish catch

Fig. 15 Experimental fishing with gill nets in Intermediate sector

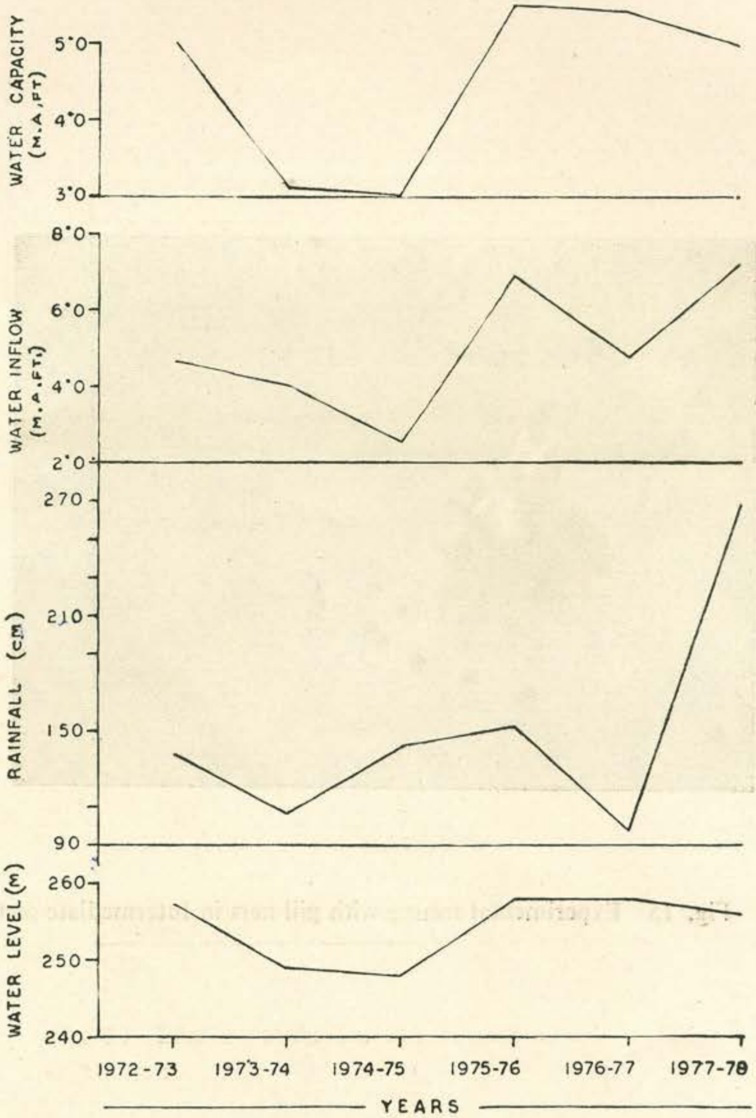


Fig. 16 Rainfall, inflow, water level and water capacity of Rihand reservoir

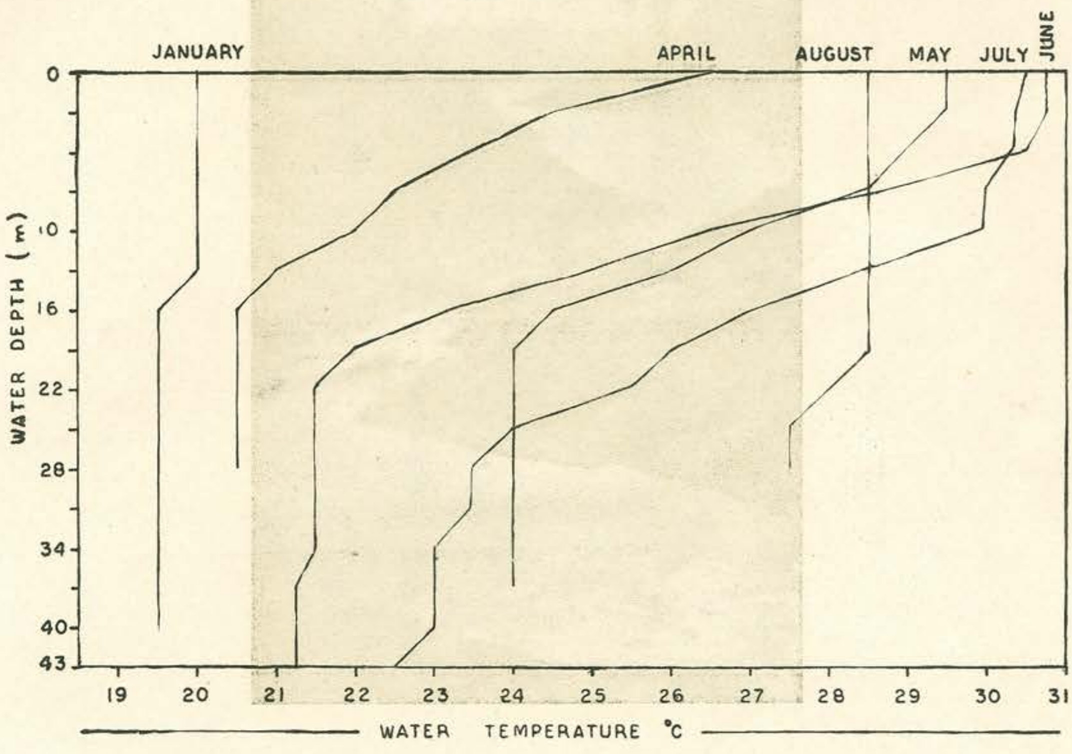


Fig. 17 Thermal stratification in Rihand reservoir

Fig. 18 Discharge of effluents of Kanoria Chemicals in Lentic sector

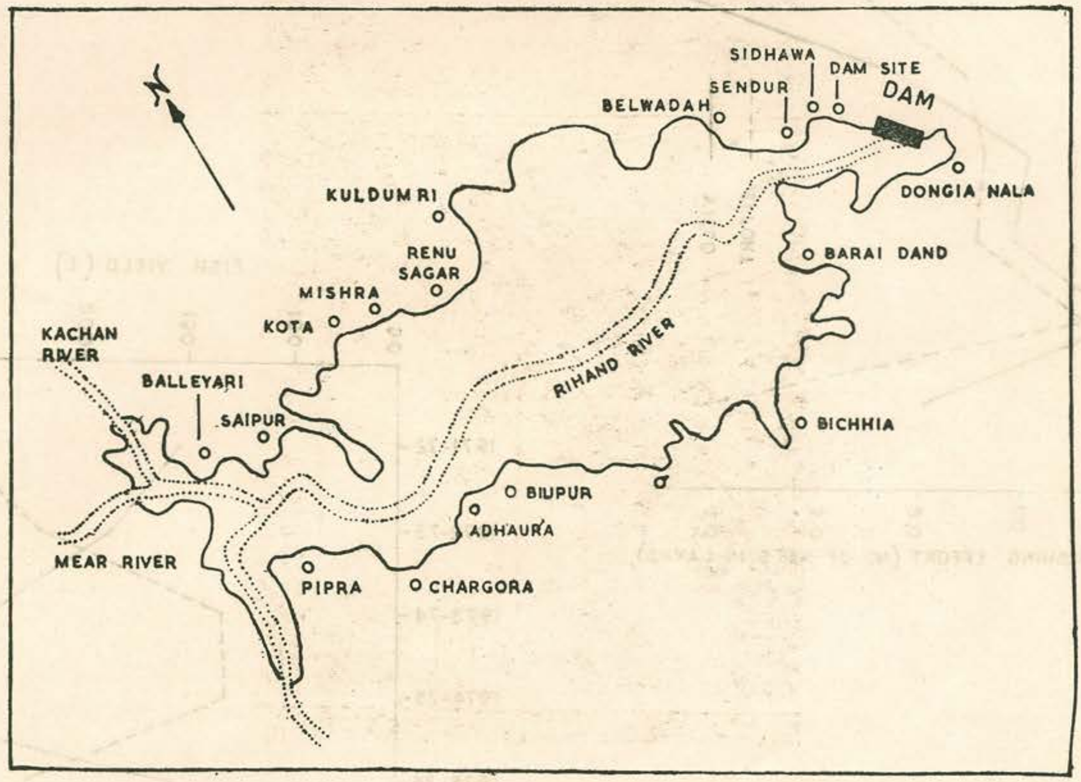
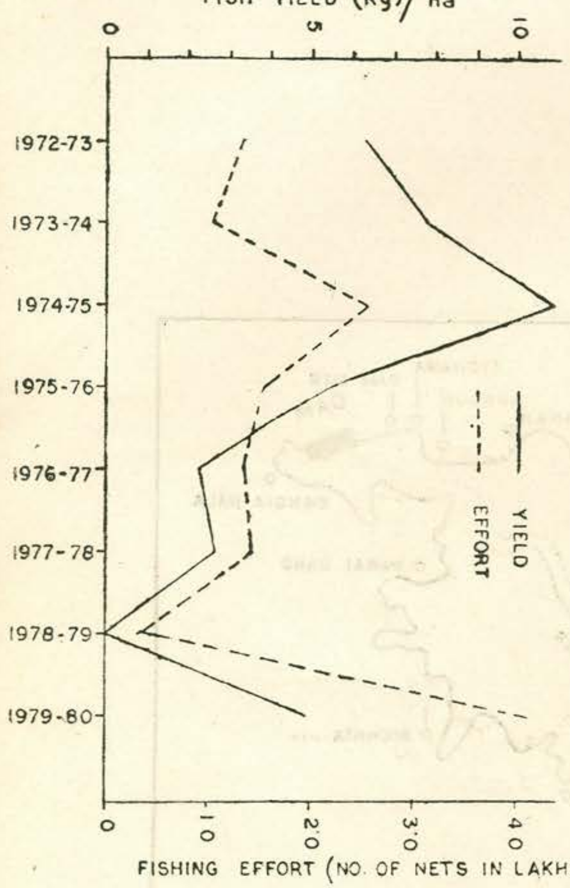


Fig. 19 Fishing centres—Rihand reservoir



< Fig. 20 Fish yield in relation to fishing effort

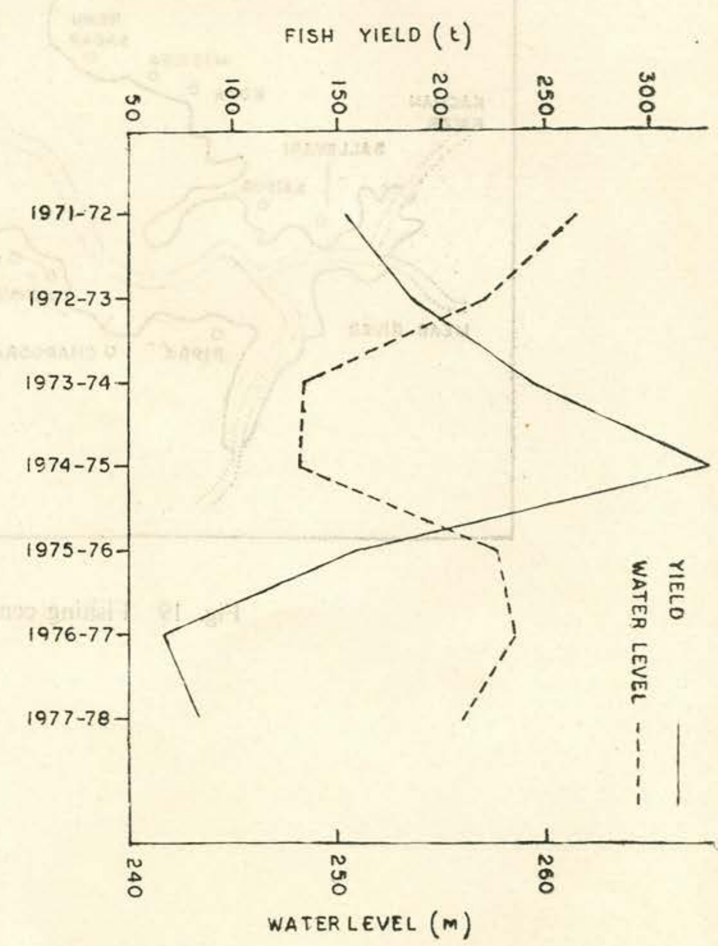


Fig. 21 Fish yield in relation to water level in Rihand reservoir >

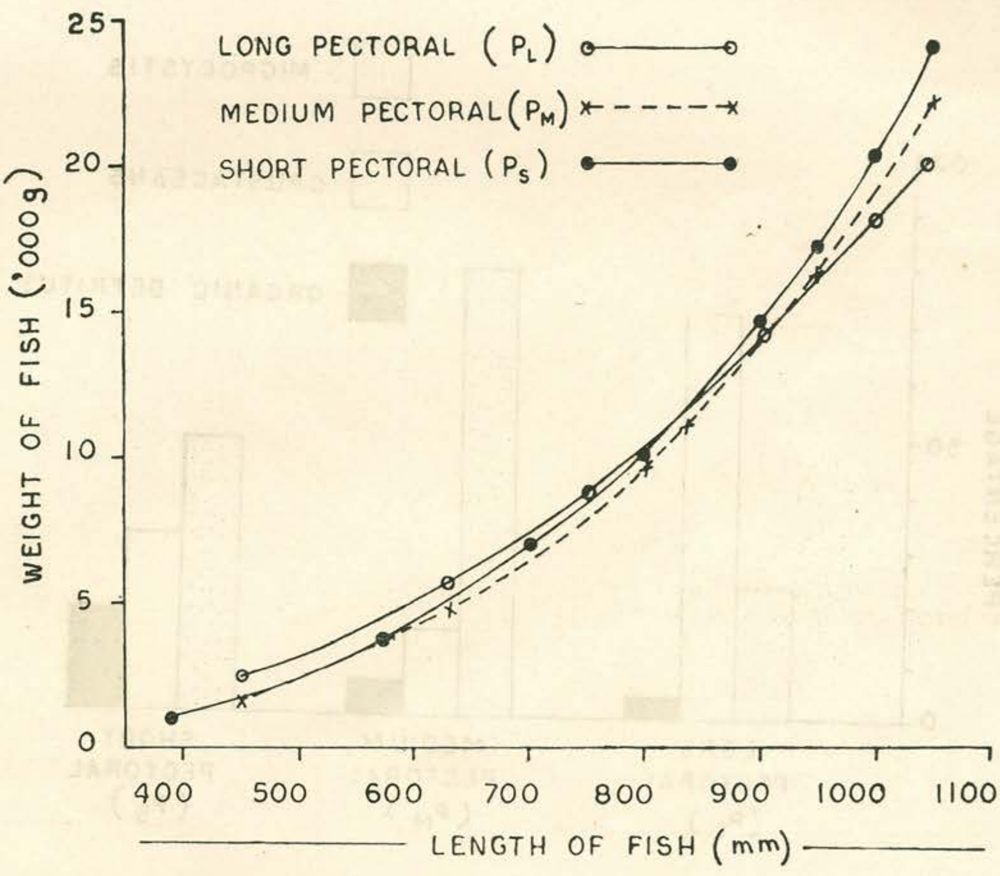


Fig. 22 Length-weight relationships of the three ecological populations of *C. catla.*

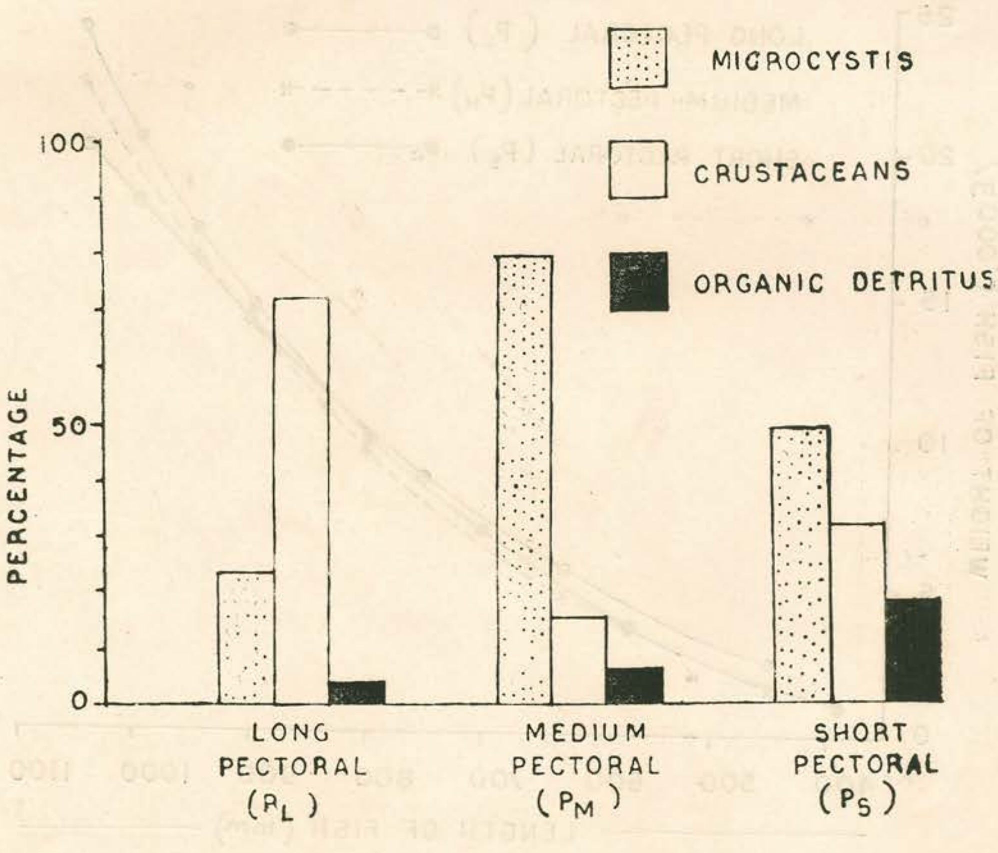


Fig. 23 Food composition of *C. catla* populations of Rihand reservoir

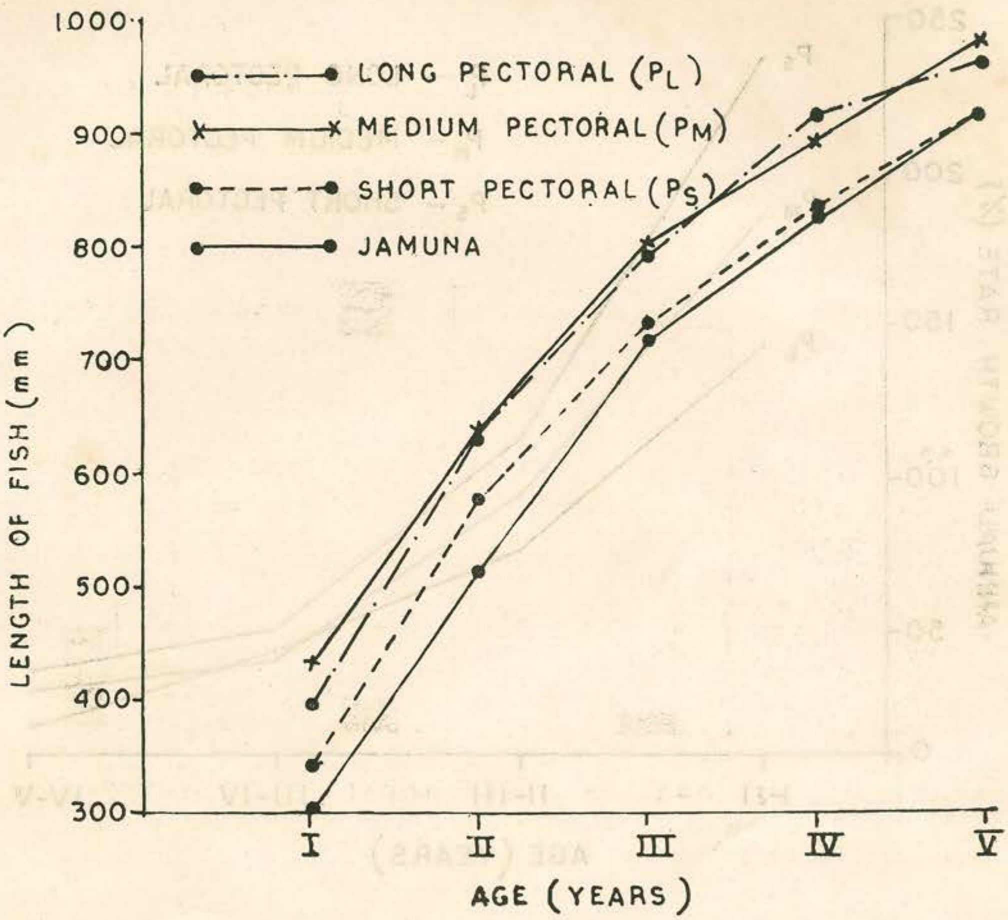


Fig. 24 Growth rate (by Weight) of *Catla* populations—Rihand reservoir

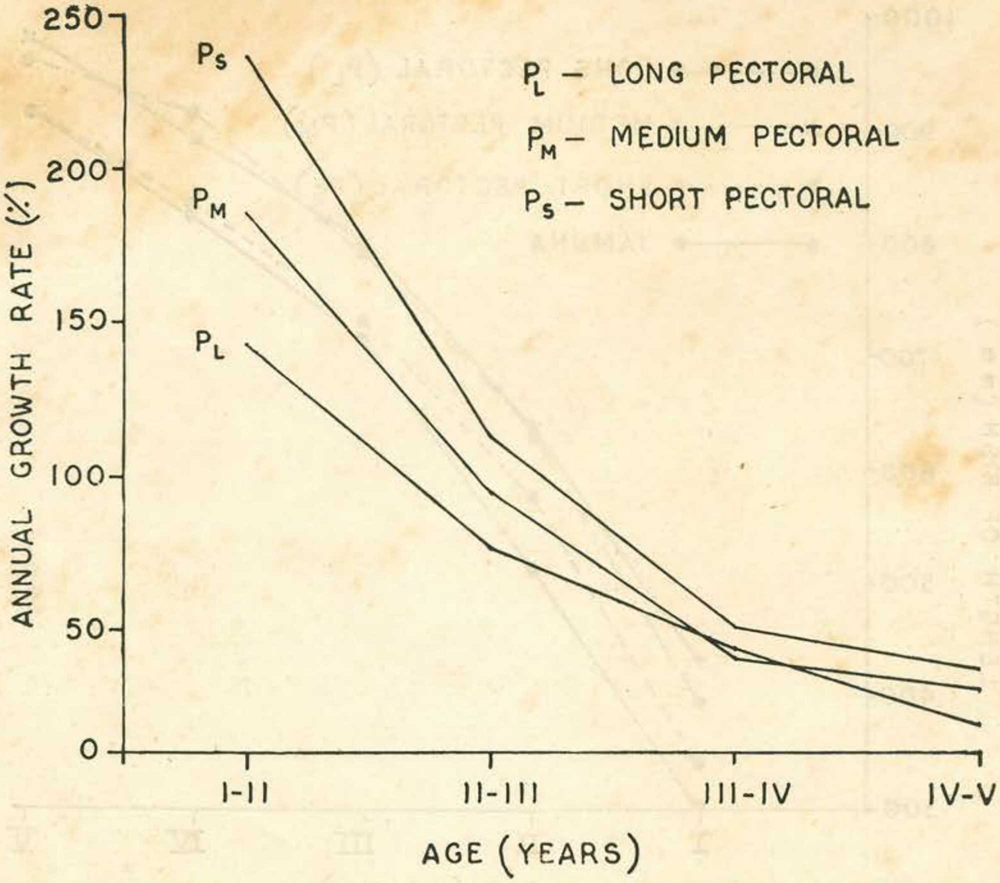


Fig. 25 Growth curves of *Catla* populations