Ecology and Fisheries of Ravishankar Sagar Reservoir

Central Inland Fisheries Research Institute
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ECOLOGY AND FISHERIES OF RAVISHANKAR SAGAR RESERVOIR

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Foreword

Reservoir fisheries development is a major area under inland fisheries development schemes of the Tenth Five Year Plan. It would be one of the main thrust areas as far as enhancement of inland fish production of India is concerned. Most of the Indian reservoirs produce fish much below their potential. To get consistent fish yields through scientific management, a proper understanding of the ecosystem is vital. With this aim in view detailed ecological investigations were carried out in Ravishankar Sagar reservoir, which is located in the nascent state of Chhattisgarh. These studies have generated enormous data on ecology and fisheries of this reservoir, which is the largest in this state. I hope the bulletin would provide useful guidelines for scientific management of the reservoir so as to enhance its fish yield, which is at its low ebb at present. Stocking is recognized as the main key for success of reservoir fisheries development. It is not possible to obtain optimum fish yield from the reservoir unless it is adequately stocked with fish seed of desired quality. It obviously needs special care and attention. I am sure that the State Fisheries Federation will take due care in this regard for obtaining maximum sustainable fish yield from the reservoir.

D.Nath
Director

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Contents

1. Introduction

The industrial and agricultural progress of the country largely depends on its water resources, particularly rivers and reservoirs. Therefore, there has been a fantastic growth of dam construction with impoundment of different river systems in India. According to Sreenivasan (1986), out of the world's water balance of 2184 million cubic kilometers, 97.2% is in the oceans, while 2.15% is locked up in the form of freshwater lakes, reservoirs, rivers, streams, ground water and saline inland seas. Thus, this limited stock of water has to be shared by all the agencies with utmost care of using it economically in view of present global conflict of water scarcity. The major uses of freshwater are: irrigation, power generation, municipal and industrial use. Priorities are being given to all the sectors but unfortunately least to fisheries. In view of this disparity in water uses, planners and policy makers should reconcile their thoughts to extract the maximum use of the minimum-the fisheries. In fact, fisheries are a 'non-consumptive' user of water, an instantaneous secondary pay-off from man-made lakes, a pay-off that can continue (Lagler, 1969).

The total water spread of Indian reservoirs is about 3 million hectares and this area is expected to double by the turn of century (National Commission on Agriculture, 1976). The present reservoir area of India is about 50 per cent of total reservoir area in Southeast Asia. However, despite having such a vast resource, the majority of these reservoirs are not being scientifically managed. Due to this reason only the per hectare fish production of Indian reservoirs is very poor, being only about 15 kg per year as against 88 kg in the USSR, 100 kg in Sri Lanka and 64.5 kg in Thailand. The reservoir area in India is bound to increase in the years to come with progressive multi-purpose river valley projects and as such there is an immense scope for developing reservoir fisheries in India. It is estimated that this sector has the potential to generate additional employment to lakhs of fishermen and workers.

Man's activities and needs are directly or indirectly responsible for the alterations in the environment. Alterations in the aquatic environment are thus forced by the needs of man for food, energy, water supply, transport and many others. Dam thus eventually changes the hydrology of rivers, both up and downstream, creating a new artificial aquatic environment. The quality of impoundment varies for different water bodies and within a watershed depending on soil, man's activities and climatic conditions. It also varies with the shape of reservoir basin and external physical factors exposure of light, wind action and rate of water exchange. Owing to these variables, the productivity of different reservoirs depending on their water quality, have to be studied for different sets or families of reservoirs sharing the same eco-climatic conditions. Moreover, the pursuance of such studies of the reservoir also aims at making planners aware of the eco-system of the area and how it reacts to the changes imposed by major engineering modifications.

2. Objectives of project study

Accordingly, with the main objectives of studying the reservoirs located in different agro-climatic conditions, a reservoir known as Ravishankar Sagar reservoir of erstwhile Madhya Pradesh, was taken up for the detailed ecological studies at the instant of Madhya Pradesh State Fisheries Corporation. The study was conducted by Central Inland Fisheries Research Institute, Barrackpore (W.B.), under the project code No.FC/A/7, with the title, "Fisheries management of freshwater resources" and sub-title, "Ecology and fisheries of Ravishankar Sagar reservoir". The data of the reservoir were collected keeping the research centre at Raipur. The objectives of the study were as below:

I. To study the ecology and dynamics of fish stocks in Ravishankar Sagar reservoir with a view to obtain sustained optimum fish production from the ecosystem.

II. To study the biology of important commercial fishes from the reservoir to evolve suitable stocking and recruitment policies for the reservoir and to adopt suitable gears and intensity of exploitation of different species.

The observations were initiated towards the end of 1986 and continued till 1993.

3. Ravishankar Sagar Reservoir - Physiographic and morphometric attributes

3.1 Location of the reservoir

Ravishankar Sagar reservoir, named after Late Pandit Ravishankar Shukla, former Chief Minister of Madhya Pradesh, came into being as a result of damming the river Mahanadi, originating in Pharsia village in Southeastern corner of Raipur district of Madhya Pradesh. It is situated 92 km to the south of Raipur in Tehsil Dhamtari within the geographical ordinates of 20°34' latitude and 81°34' longitudes. Owing to construction of dam at village Gangrel, the reservoir is also known as Gangrel reservoir. The area experiences an average annual rainfall of about 125 cm with the high degree of yearly variation.

The Mahanadi River drains an area of 141600 sq.km of which 53.0% is in erstwhile Madhya Pradesh, 46.4% in Orissa and 0.6% in Bihar. The total length of the river is 857 km and has a maximum discharge of 44740 cubic m. sec. and an annual flow of 66640 mcm.

3.2 Description of the reservoir

The reservoir has a total catchment area of 3670 sq.km and is the largest reservoir in Chhattisgarh. It has a gross storage capacity of 909.3 mcm and water spread of 9540 ha at FRL. The reservoir water level fluctuates between FRL of 348.70 m and DSL of 336.21 m. The maximum and mean depths of the reservoir at FRL are 32.0 m and 10.0 m respectively. The shoreline and shore development of reservoir are 102.4 km and 2.96 respectively. The volume development of reservoir being less than 1 (0.94) indicates convex shape of the basin. The reservoir extends 25 km in length and 15 km in breadth.

3.3 History of the reservoir

The erection of Gangrel dam was initiated in 1973 and consequently the Mahanadi was impounded in 1978 to emerge out as Ravishankar Sagar reservoir. The main purpose of constructing the reservoir was irrigation and partially hydel but presently the reservoir water is also being used for drinking purpose and to meet out the demand of Bhilai Steel Plant, located nearby in district Durg. The reservoir was taken up by Madhya Pradesh State Fisheries Department for stocking of fish and its exploitation quite late after 5 years in 1983. The detailed ecological studies of the reservoir in relation to its fisheries were not undertaken by any source till 1986, the year of inception of its study by CIFRI. At the time of commencement of this study, the fish yield of the reservoir was very low to the tune of 12.0 t/year (2.0 kg/ha/y).

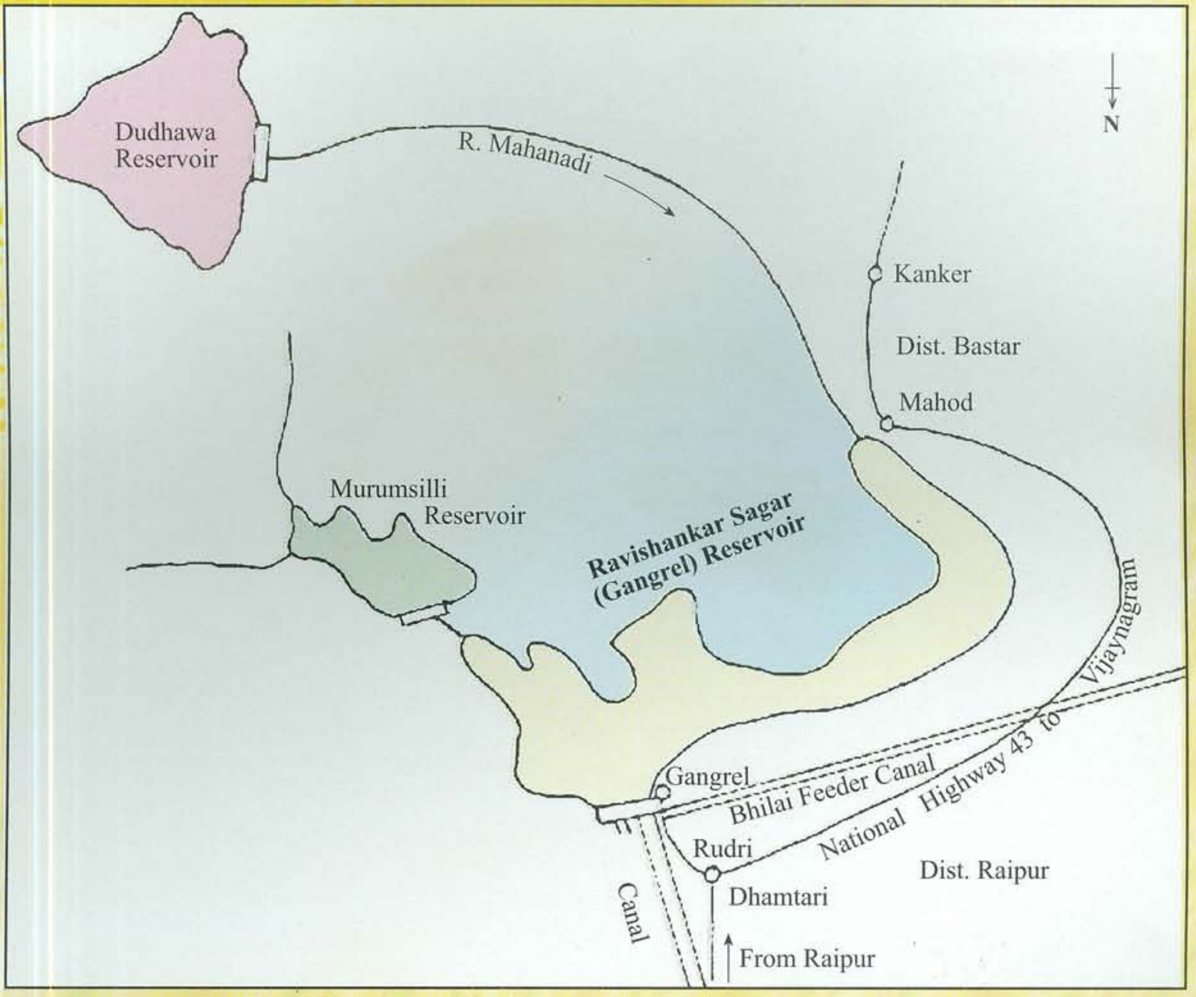


Fig. 1 : Location of Ravishankar Sagar reservoir in relation to Murumsilli and Dudhawa reservoir

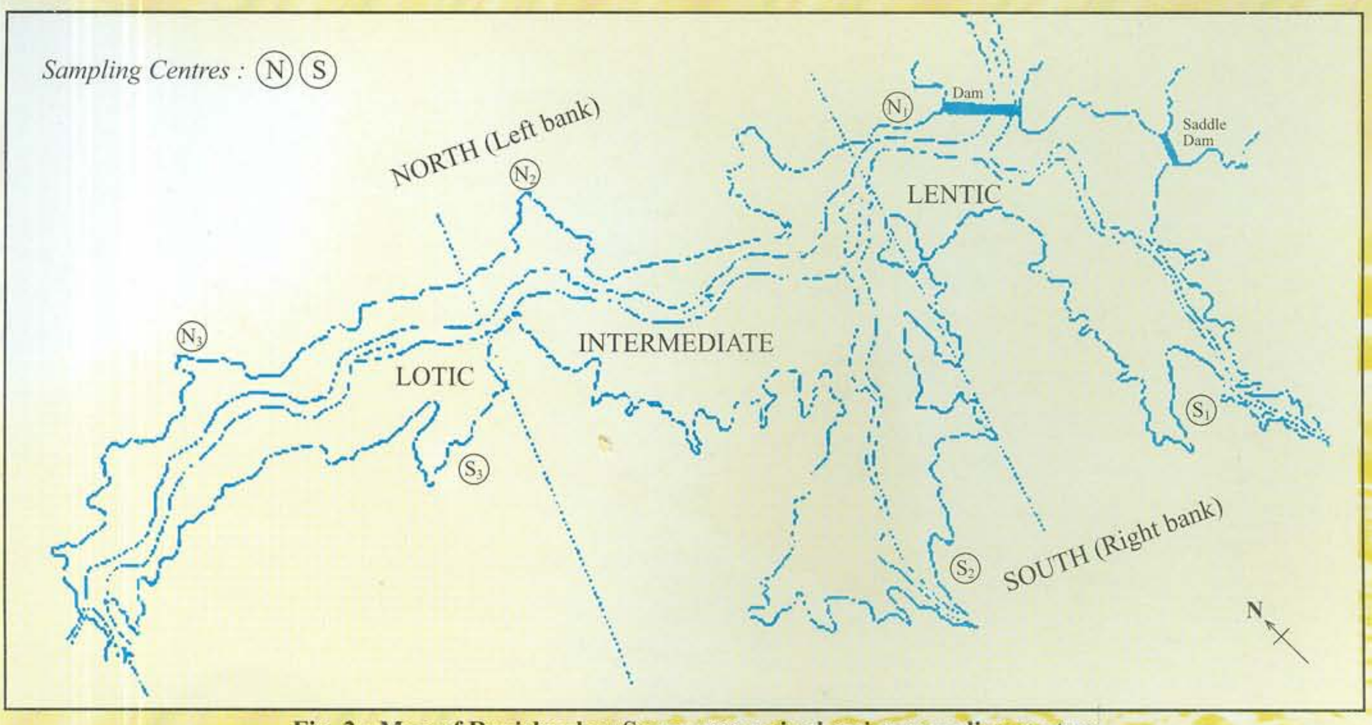


Fig. 2 : Map of Ravishankar Sagar reservoir showing sampling centres

3.4 Water drainage of reservoir

The River Mahanadi from its origin to the location of Ravishankar Sagar reservoir covers a stretch of 115 km and in halfway of this stretch the river was also impounded earlier long back in 1962 to have a reservoir known as Dudhawa reservoir in District Baster (Jagdalpur). Thus, apart from receiving the water from its own catchment area, the Ravishankar Sagar reservoir also gets water from the top, outflow from Dudhawa reservoir and from another reservoir – Murumsilli, located along southern side of Ravishankar Sagar reservoir. The water thus stored in Ravishankar Sagar reservoir from the above resources, is regularly out flown through irrigation and Bhilai feeder canals. Looking to this drainage system of the reservoir, it rarely attains stagnancy in its water level as basically required to build up the biological productivity of the ecosystem. In other words it may be said that Ravishankar Sagar reservoir is a balancing intermediary water body, with the receipt of monsoon inflow and discharge from Dudhawa reservoir and draw down to Bhilai Steel Plant and through irrigation canal, which may be a process to continue throughout the year. Owing to these characteristics, the reservoir is almost a 'fluviatile' lake with lesser period of water retention.

The location of Ravishankar Sagar reservoir in relation to Dudhawa and Murumsilli reservoirs is shown in Fig.1.

Morphometric features of Ravishankar Sagar reservoir

General

Location	:	District Raipur
Name of the river	:	Mahanadi
Year of commissioning	:	1978
Purpose	:	Irrigation and Hydel, domestic use and for Bhilai Steel Plant

The Lake

Geographical ordinates	: 20°34' latitude
	: 81°34' longitude
Full reservoir level (m)	: 348.70
Dead storage level (m)	: 336.21
Catchment area (km^2)	: 3670
Gross storage capacity (x $10^6 m^3$)	: 909.3
Dead storage capacity (x $10^6 m^3$)	: 143.60
Water spread area at FRL (ha)	: 9540
Water spread area at DSL (ha)	: 3214
Mean depth (m)	: 10.0
Length of shore line (km)	: 102.4
Shore development index	: 2.96
Volume development index	: 0.9

Masonry dam

Length of dam spillway portion (m)	: 252.25
Spillway gates	: 14 nos. (15.0 m x 10.0 m)
Maximum height of dam (m)	: 32

Earthen dam

Length of main dam (m)	: 1245.75
Length of saddle dam (m)	: 1110.00
Maximum height of main dam (m)	: 30.5

4. Sampling procedure

. The sampling and analytical procedures for the reservoir were followed as per the techniques given in '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. In each sector, sampling was done once a month covering two centres, lying opposite each other in Northern and Southern banks of the reservoir. The map of the reservoir showing the three sectors and the sampling centres is shown in Fig.2.

5. Meteorological observations

5.1 Air temperature

The air temperature ranged from 19.0°c (January) to 35.0°c (April) with one peak, not showing double oscillations through two peaks.

5.2 Rainfall

The rainfall, which was moderate in 1987-88 (1043.25 mm), gradually decreased till 1989-90 (821.10 mm) but suddenly increased in 1990-91 (1783.65 mm) to decrease further in 1991-92 (1418.80 mm) and 1992-93 (1159.60 mm). Since the breeding success of major carps is mainly influenced by the rainfall of July in particular, certainly the anxiety lies in knowing the rainfall of July. With this angle the data indicated that July rainfall was highest in 1991-92 (495.60 mm) but in other years it ranged from 146.00 mm to 305.80 mm.

6. Physical features of reservoir water

6.1 Water level

The average water level of the reservoir which fluctuated within a narrow range of 338.76-339.49 m during 1987-88 to 1989-90, suddenly rose to 344.62 m in 1990-91 and continued to keep high level in 1991-92 (345.65 m) and 1992-93 (344.28 m). It was an impact of high degree of rainfall recorded during these years, particularly in 1990-91. The reservoir water level did not attain FRL from 1987-88 to 1989-90 but it attained during 1990-91 to 1992-93. While the reservoir reached FRL in August during 1990-91, in 1991-92 the attainment was earlier in July due to high monthly rainfall of this year. But subsequently in 1992-93, the attainment of FRL was again delayed till August.

6.2 Water capacity

The water capacity of the reservoir fully followed the trend of water level. The water capacity which was moderate in 1987-88 (282.08 mcm), decreased in 1988-89 (238.04 mcm) again improved in 1989-90 (284.86 mcm) and suddenly increased in 1990-91 (608.03 mcm) to maintain the high level in 1991-92 (650.49 mcm) and 1992-93 (556.14 mcm).

6.3 Water inflow

The water inflow is entirely governed by the rainfall and as such the yearly trend of water inflow clearly tallied with the rainfall data. The water inflow, which was moderate in 1987-88 (1.038×10^9 m^3) was reduced in 1988-89 ($0.6683 \times 10^9 m^3$) and 1989-90 (0.7934×10^9 m^3), but abruptly increased in 1990-91 ($3.340 \times 10^9 m^3$) due to high rainfall of this year. During 1991-92 (2.202×10^9 $m^{3)}$ and 1992-93 (1.955×10^9 m^3), the inflow of water was normal.

6.4 Water outflow

The outflow of water was dependent on its inflow. Consequently the water outflow which gradually decreased from 0.9491×10^9 m^3 (1987-88) to 0.641×10^9 m^3 (1989-90), suddenly increased to 2.864×10^9 m^3 (1990-91) and ranged from 2.426×10^9 m^3 to 2.003×10^9 m^3 during 1991-92 to 1992-93.

6.5 Water evaporation

The water evaporation loss which was more or less the same in 1989-90 and 1990-91 ($0.030\text{-}0.036 \times 10^9$ m^3), increased in 1991-92 (0.055×10^9 m^3) and dropped down to 0.037×10^9 m^3 in 1992-93. It may be stated that in 1991-92 the evaporation of water was more with availability of greatest water spread (8500 ha) and highest water level (345.64 m).

7. Physico-chemical features of water

7.1 Surface water

7.1.1 Physical parameters

The parameters estimated from surface waters of lentic, intermediate and lotic sectors of the reservoir were temperature and transparency.

Water temperature ranged from 21.0°c (January) to 29.5°c (March/May) with one peak, not showing double oscillation through two peaks.

Water transparency was found to range from 15 cm (Aug-Sep) to 124 cm (May). Accordingly, the euphotic zone calculated from transparency values also showed the same trend varying from 0.4 to 3.1 m, the average being 1.5 m. The extinction co-efficient exhibited indirect relationship with water transparency and euphotic zone (Fig.3), fluctuating from 0.014 (May) to 0.113 (Aug-Sep). The water transparency in deeper waters of the reservoir (lentic and intermediate sectors) and the corresponding euphotic zone were more.

7.1.2 Chemical parameters

The dissolved O_2 ranged from 6.9 mg l^{-1} (Nov) to 9.8 mg l^{-1} (Jan) with the mean value of 8.4 mg l^{-1}. The free CO_2 was absent from April to July but occurred from August to March (Range: 0.5 to 8.0 mg l^{-1}; Av. 1.4 mg l^{-1}), being highest in August. The total alkalinity ranged from 43.3 mg l^{-1} (Aug) to 85.3 mg l^{-1} (Feb) with the average being 66.8 mg l^{-1}. Of the mean value of total alkalinity, the contribution of carbonates and bicarbonates were 3.5 mg l^{-1} and 63.3 mg l^{-1} respectively. The average total hardness (49.5 mg l^{-1}) also fairly agreed with total alkalinity. Based on total alkalinity and total hardness, the reservoir may be classified as medium productive. In the absence of free CO_2 the marls produced during photosynthesis are known to settle on the bottom (Welch, 1952) and due to this reason the total alkalinity was moderate. The high content of C_a (38.5 mg l^{-1}) in total hardness also speaks of the presence of greater population of molluscs and supported by the annual availability of *Chara* in December. The occurrence of free CO_2 in August may be attributed to the draw down of decayed organic matter in the reservoir by the monsoon inflow and also to putrification of macrophytes, already present in the reservoir, on their submergence under water. The mean values of phosphates (0.07 mg l^{-1}) and nitrates (0.05 mg l^{-1}) also supported the medium productivity of the reservoir. The electrical conductivity ranged from 46.3 micro-mhos cm^{-1} (Aug) to 97.0 micro-mhos cm^{-1} (May) with the mean being 68.3 micro-mhos cm^{-1}. The total dissolved solids (TDS) varied from 23.1 mg l^{-1} (Aug) to 49.0 mg l^{-1} (May) with the mean being 34.1 mg l^{-1}. The morpho-edaphic index of the reservoir was calculated on the basis of TDS. The pH ranged from 7.6 to 8.4 (mean: 8.1) with the lowest being during monsoon (Jul-Sep).

7.1.3 Diurnal variations in chemical parameters

The diurnal variations at 6, 12, 18, 24 hrs in respect of dissolved O_2, free CO_2, total alkalinity (carbonate and bicarbonates), pH and specific conductivity were studied in summer, monsoon and winter seasons. Studies revealed that of the above five chemical parameters, only dissolved O_2 during summer progressively increased from 6 to 24 hours. None of the other parameters showed diurnal changes in any season, which clearly indicate the poor photosynthetic activities in the reservoir, as also supported by moderate primary production.

7.2 Sub-surface water

Observations indicated that even in summer (April –June) the water temperature and other chemical parameters did not show well-marked variation from surface to bottom layers. While in summer the water temperature slightly decreased from surface (29.5°c) to bottom water (25.0°c) registering a fall of 4.5°c only and during rest of the period the temperature was more or less uniform (isothermal condition). Similarly, only in April, the dissolved O_2 decreased from surface to bottom (8.5 to 5.8 mg l^{-1}) whereas total alkalinity (70.0 to 82.0 mg l^{-1}) and specific conductivity (73.0 to 81.0 micro-mhos cm^{-1}) increased from surface to bottom. Thus, the condition of water was *holomixis* during most of the year, not showing distinct thermal or chemical stratification even in summer. Absence of stratification in the reservoir was already expected looking to round the year flowing condition of this irrigation impoundment, which is also shallow with the mean depth of 10 m only at FRL. In this context it may be commented that looking to the little klinograde distribution of dissolved O_2 in the depth profile as noted in April, the reservoir appeared to show slight tendency towards

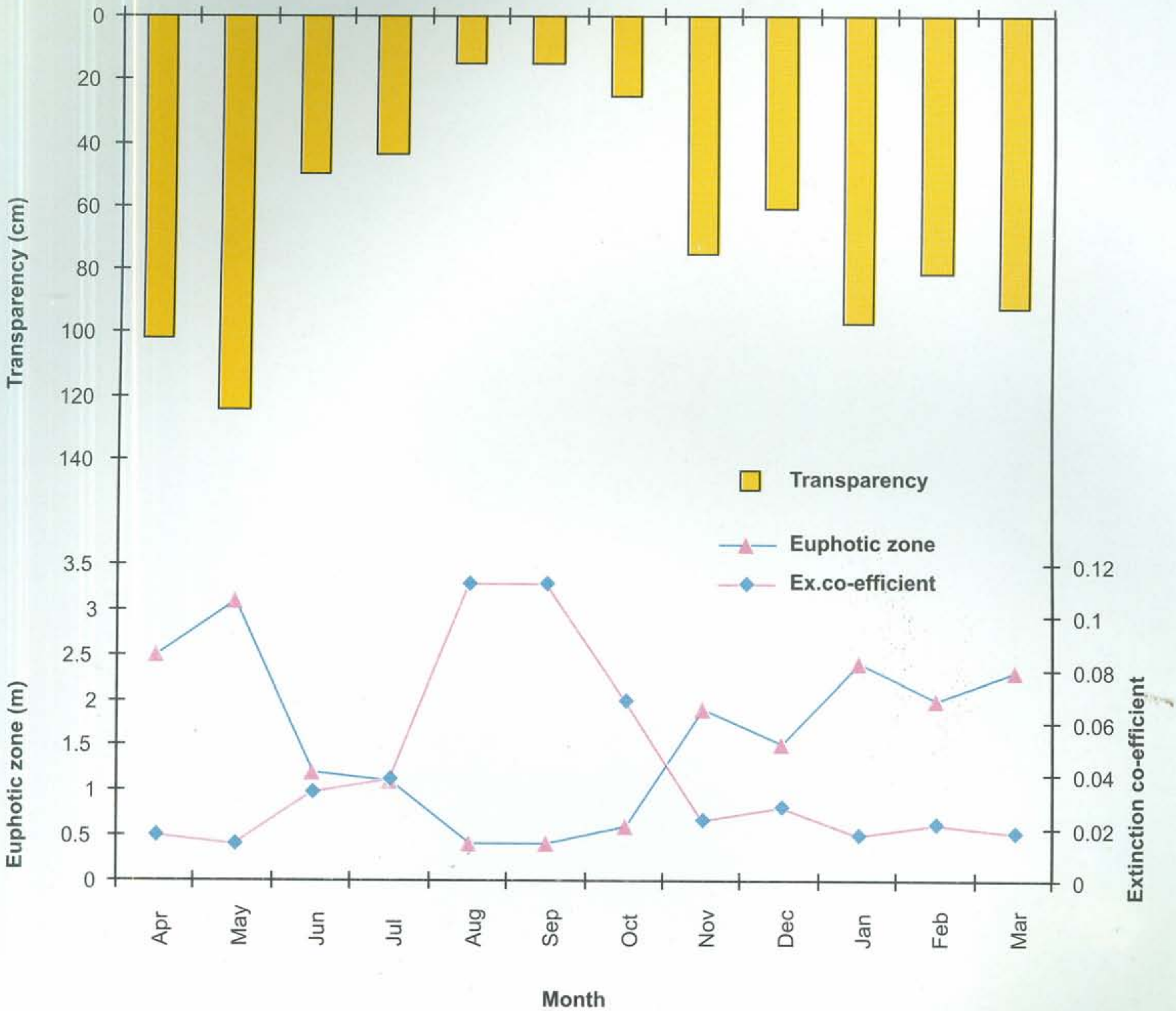


Fig. 3 : Monthly variation in overall water transparency, euphotic zone and extinction co-efficient of Ravishankar Sagar Reservoir

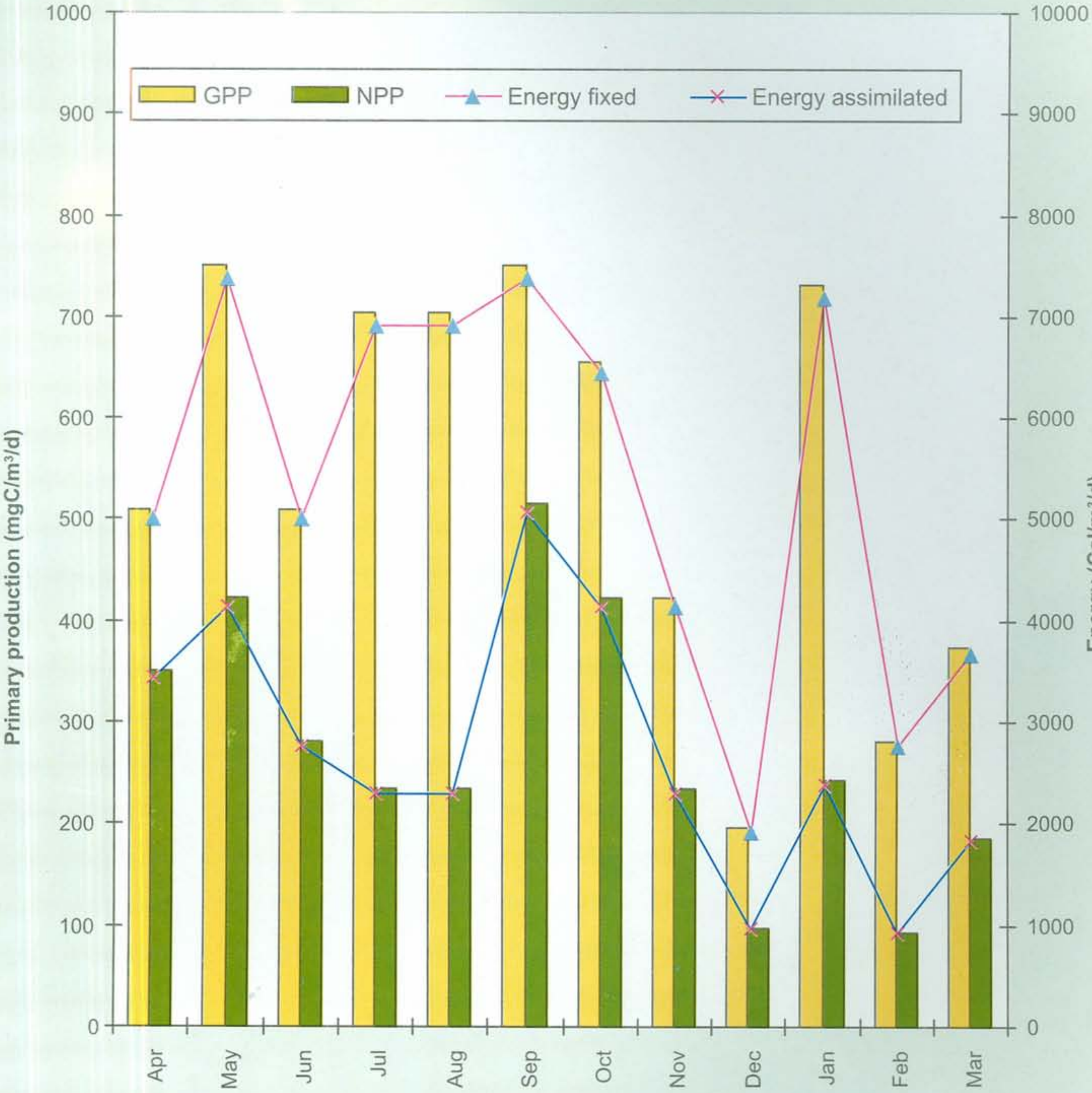


Fig. 4 : Primary production and energy transformation in Ravishankar Sagar Reservoir (1992-93)

formation of a weak oxycline but it was not possible in the present case due to inflowing condition of water even in summer.

8. Primary production

8.1 Gross/net production

The gross primary production ranged from 196.8 to 750.0 $mgC/m^3/d$, the net primary production varied from 93.7 to 516.0 $mgC/m^3/d$. The gross and net productions were high all the year round excepting the lowest values recorded in December. Thus, the monthly variation in the primary production of the reservoir did not show distinct peaks in conformity to plankton abundance, which may be due to subdued occurrence of phytoplankton and overall predominance of zooplankton in the reservoir. The average annual gross and net productions were found to be 509.98 and 276.53 $mgC/m^3/d$. The monthly variations in primary production along with energy transformation are depicted in Fig.4.

8.2 Energy assimilation

The gross energy fixed by producers was in the range of 1933.68 to 7369.20 $cal/m^3/d$. The average rate of gross energy transformation by producers comes to 5010.82 $cal/m^3/d$. Similarly, the net energy fixed by producers fluctuated from 920.85 to 5070.01 $cal/m^3/d$ with the average being 2717.07 $cal/m^3/d$. Based on this information, the average annual energy lost during the process of respiration was estimated at 2293.75 $cal/m^3/d$. Accordingly, the energy assimilation efficiency was worked out to be 54.2 which is much nearer to the values of the productive reservoirs studied under AICRP like Bhavanisagar (52.0%), Nagarjunasagar (58.0%) and Govindsagar (65.0%). Rihand reservoir (41.0%) was less productive.

8.3 Potential fish yield

From primary production studies of Ravishankar Sagar reservoir it is estimated that potential fish production of 25 kg/ha/A (= 160 t/A) can be exploited from it. As against this, the actual maximum fish production from the reservoir in the year 1991-92 was 9 kg/ha/A (= 53 t/A). Thus, only 33.0% of the potential is actually being harvested from this reservoir and hence still there is scope for further development of the reservoir fishery.

8.4 Conversion value

The average primary net production of the reservoir was estimated as 300 $mgC/m^3/d$. Based on this rate of primary production, the different conversion values were calculated. The annual average carbon production of the entire reservoir was 7000 t (= 1097 kg/ha/A). As the carbon values divided by 0.44 gives the dry weight of planktonic biomass (Waldickuk, 1958), the total biomass in the reservoir comes to 15,909.09 t. Considering that 100 kg of dry plankton yield 1 kg of fish, the harvest from Ravishankar Sagar reservoir should have been 159.0 t/Y. The actual harvest from the reservoir was 50.0 t/A. Thus, only 0.31 part of the potential fish yield is being harvested from this reservoir. According to Vinlgradov (1953), the average protein content of fish is 20% of which 50% could be reckoned as carbon *i.e.* 10% of weight of fish. Thus, the fish landing of Ravishankar Sagar reservoir represented 5.0 t of carbon and as such the initial carbon stock of 7000 t of the entire reservoir, only 0.07% is being converted into carbon in the form of fish. Similarly, with the initial stock of carbon/ha/A of the reservoir (1097 kg), 8 kg/ha/A of fish is being harvested thereby showing utilization of 0.7% of the carbon stock towards the formation of fish flesh. The above conversion values appeared to be moderate as compared to those of other reservoirs.

8.5 Potential fish yield from Morpho-edaphic and Morpho-drainage indices

Apart from estimating the potential fish yield with trophodynamic model, the yield was also estimated with Morpho-edaphic index (Ryder model) and Morpho-drainage index (Ramakrishniah). The data are depicted in Fig.5. The mean depth of the reservoir was lowest in 1990 (5.8 m), highest in 1991 (7.9 m) and intermediary in 1992 (6.7 m). The MEI and MDI which were found to be 6.9 and 9.4 respectively in 1990, decreased in 1991 (4.5 and 5.2 respectively) with the increase in depth. But in 1992 with the fall in mean depth, the indices again increased to 5.3 and 6.6 respectively. Thus, an inverse correlation was found between the mean depth and production indices of the reservoir. Based on MEI and MDI of the reservoir, the fish yield/ha/A was also determined. While the fish yield as per MEI ranged from 16.0 to 19.0 kg/ha/A, the MDI indicated the fish yield ranging from 18.0 to 33.0 kg/ha/A. It is evident that production potential expressed by MEI is on a lower side than that of MDI. However, the estimates (16-33 kg/ha/A) are around the vicinity of the values ascertained from the studies of primary production.

9. Physico-chemical features of soil

The study of basin soil of the reservoir in respect of important chemical parameters like pH, organic carbon, total nitrogen, C: N ratio, available nitrogen and phosphorus are of paramount importance because the water quality and biological productivity of the reservoir are largely dependent on its basin soil. In this context it is worthwhile to mention here that catchment area of Ravishankar Sagar reservoir is mainly constituted by forest area, which is not being under cultivation at any stage.

9.1 Soil characteristics in pre/ post-monsoons and overall status

The data collected separately from lentic, intermediate and lotic sectors of the reservoir during pre-monsoon and post-monsoon seasons indicated that none of the characteristics of bottom soil of the reservoir showed any remarkable change. The organic carbon which indicated little values during pre-monsoon, decreased after monsoon but specific conductivity improved during post-monsoon. As seen from the overall values, the organic carbon of the soil was of average category (0.8%). If this organic carbon is multiplied with 1.72 (factor to convert organic carbon into organic matter), the organic matter comes to 1.4%, which suggests that source of organic matter through autochthonous and allochthonous was of moderate strength because soil containing 4% of organic matter possesses normal source of potential energy. The organic matter of basin soil of Bhavanisagar was 3.9%, 1.68% in Nagarjunasagar, 1% in Rihand, 0.8% in Getalsud and 3.4% in Govindsagar reservoirs. Soil was always acidic in reaction with pH ranging from 5.9-7.3. Due to acidic nature of the soil, the available phosphorus (3.9 mg 100 g^{-1}) was poor being in soluble form. The other nutrient, available nitrogen (12.0 mg 100 g^{-1}) was also poor but the C: N ratio (9:1) was ideal for better production because C: N ratio above 15:1 appears to be less favourable. The soil was found sandy in texture containing some clay and silt with average value of specific conductivity (442.08 micro-mhos cm^{-1}). Going by the chemical parameters of bottom mud of Ravishankar Sagar reservoir, it can be assigned to average group for fish production.

10. Biotic communities

10.1 Plankton

The samples were collected through vertical hauls from lentic, intermediate and lotic sectors of the reservoir and analysed numerically as well as volumetrically.

10.1.1 Variations in plankton abundance

The plankton population was more or less of the same magnitude (1329 to 1575 ul^{-1}; 0.77 to 0.87 ml/m^3) during the period of three years (1989-90 to 1991-92), being the highest in 1991-92. As seen from the overall monthly distribution of three years, the plankton exhibited 2-3 peaks in a year with slight variations. In 1989-90 the summer peak was seen in May, which was followed by a very distinct monsoon peak in September whereas the winter peak was not so significant. In 1990-91 the summer peak continued to be in May, which was quite pronounced (4062 ul^{-1}; 2.04 ml/m^3). Plankton was poor during monsoons and later the winter peak was observed in February. In 1991-92 though no peak was seen in May, plankton abundance was later observed distinctly in July followed by three peaks in September, November and February. As seen from repeated occurrence of peaks and so also from the yearly greater density, the plankton population was comparatively more in 1991-92. While correlating this data with that of water inflow, it was observed that inflow of water into the reservoir from its catchment area during monsoons was also high in 1991-92 (1.5 TMC/M) which was the main contributory factor to enrich the ecosystem with nutrients and thereby to improve the plankton population of the reservoir.

10.1.2 Sectorly variation

The plankton was more or less uniformly distributed in the three sectors during the entire period of three years excepting 1991-92 when lotic sector had more plankton (2216 ul^{-1}) than that of lentic (1411 ul^{-1}) and intermediate (1154 ul^{-1}) sectors. The volumetric analysis of plankton also supported the same trend of sectorly distribution.

10.1.3. Variation along the banks

The plankton population did not show any remarkable change. While the plankton of North bank ranged from 1413-1657 ul^{-1} (=0.85-0.89 ml/m^3), that of South bank varied from 1145-1663 ul^{-1} (=0.66-0.89 ml/m^3).

10.1.4 Quality composition and its yearly variation

The quality composition of plankton determined during the course of study is shown in pie diagrams (Fig.6). It is very clear from these illustrations that there was an overall throughout dominance of zooplankton (79.9 to 87.8%) in the reservoir against the subdued occurrence of phytoplankton in the reservoir, being due to two factors, firstly on account of constantly flowing water condition of the irrigation reservoir and secondly due to grazing effect of zooplankton and minnow fish –the dominant fish population of the reservoir, both being the primary consumers of phytoplankton. Among the zooplankton, Copepods (37.6 to 49.2%) were the most dominating followed by Rotifers (15.0 to 23.6%), Cladocerans (10.8 to 14.1%), Protozoans (2.9 to 9.1%) and Anostracans (0.6 to 1.5%). Myxophyceae (3.8 to 13.3%), Chlorophyceae (3.7 to 5.1%), Bacillariophyceae (2.7 to 4.7%) and Dinophyceae

(0.2%) represented the poor quality of phytoplankton. The quality of plankton with regard to different forms recorded from the reservoir is listed below:

Zooplankton

Copepods :	*Diaptomus, Cyclops,* Nauplii
Cladocerans :	*Daphnia, Bosmina, Chydorus, Moina, Ceriodaphnia, Diaphanosoma, Acroperus, Macrothrix, Sida*
Rotifers :	*Keratella, Brachionus, Filinia, Ployarthra, Asplanchna, Trichocerca, Mytilina, Lecane, Conochilus, Colurella, Diplois, Synchaeta, Notholca, Epiphanes, Hexarthra, Monostyla*
Protozoans :	*Difflugia, Centropyxis, Arcella, Euglypha, Urostyla, Trinema, Euglena*
Anostracans :	*Eubranchipus, Pristicephalus*

Phytoplankton

Myxophyceae :	*Microcystis, Oscillatoria, Anabaena, Nostoc, Phormidium, Spirulina, Chroccoccus, Coelosphaerium, Merismopedia, Gomphosphaeria*
Chlorophyceae :	*Pediastrum, Spirogyra, Coelastrum, Cosmarium, Volvox, Pandorina Actidesmium, Closterium, Desmidium,Staurastrum, Ankistrodesmus, Crucigenia, Actinastrum, Microspora, Gonatozygon, Ulothrix, Treubaria, Basicladia*
Bacillariophyceae:	*Navicula, Fragilaria, Synedra, Gyrosigma, Melosira, Surirella, Cymbella, Gomphonema, Rhopalodia, Meridion, Cocconeis, Amphora, Cyclotella, Pinnularia, Nitzschia, Diploneis*
Dinophyceae :	*Ceratium, Peridinium*

10.1.5 Diurnal variations

During summer plankton availability was more at 6.0 and 12.0 hours but later it declined. The plankton concentration of 12.0 hours was maximal with equal distribution of phyto and zooplankton, which was not recorded in other seasons. While during monsoon the plankton was more only at 6.0 hours, in winter the density was more at 6.0 and 24.0 hours. As stated above, excepting 12.0 hours of summer there was an overall dominance of zooplankton in all the observations. The plankton productivity was highest only in summer as compared to other seasons.

10.2 Macrobenthos

The study with the relevance to the fishes feeding on bottom biota was conducted for three years (1989-90 to 1991-92).

10.2.1 Annual and monthly variations in abundance

The overall macrobenthic population of the reservoir, which was estimated to be 418 nos/m^2 in 1989-90, declined to 281 nos/m^2 in 1990-91 and again increased to 570 nos/m^2 in 1991-92. The population in terms of weight during 1991-92 was found to be 143.95 g/m^2. Though the density of bottom biota fluctuated within the narrow range of 281-570 nos/m^2, its monthly abundance indicated remarkable variations depending on the summer water level of the reservoir and the monsoon inflow. In 1989-90 (30-805 nos/m^2) the bottom biota after

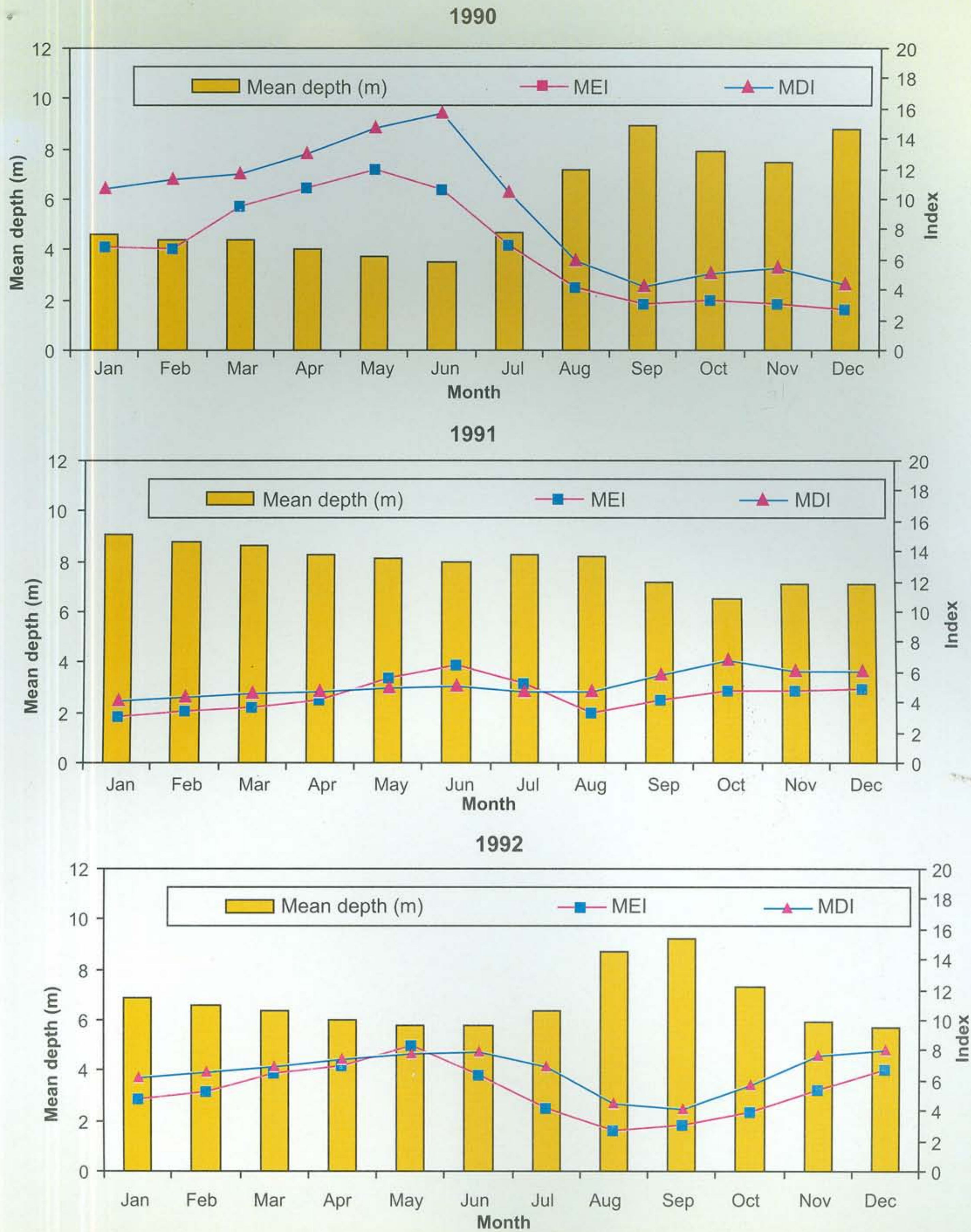


Fig. 5 : Monthly variation in mean depth, morpho-edaphic index (MEI) and morpho-drainage index (MDI) of Ravishankar Sagar reservoir

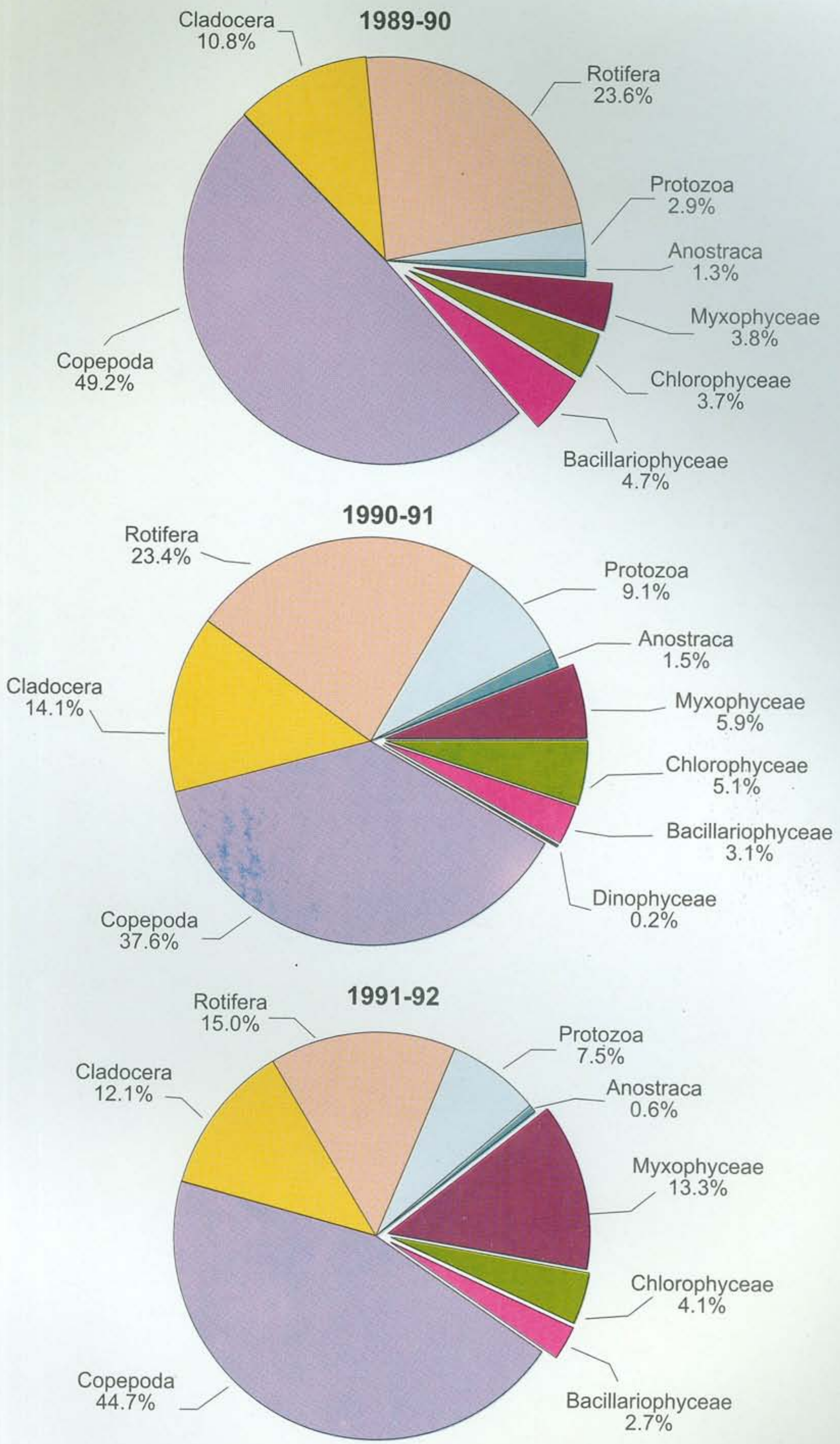


Fig. 6 : Quality composition (%) of plankton of Ravishankar Sagar Reservoir

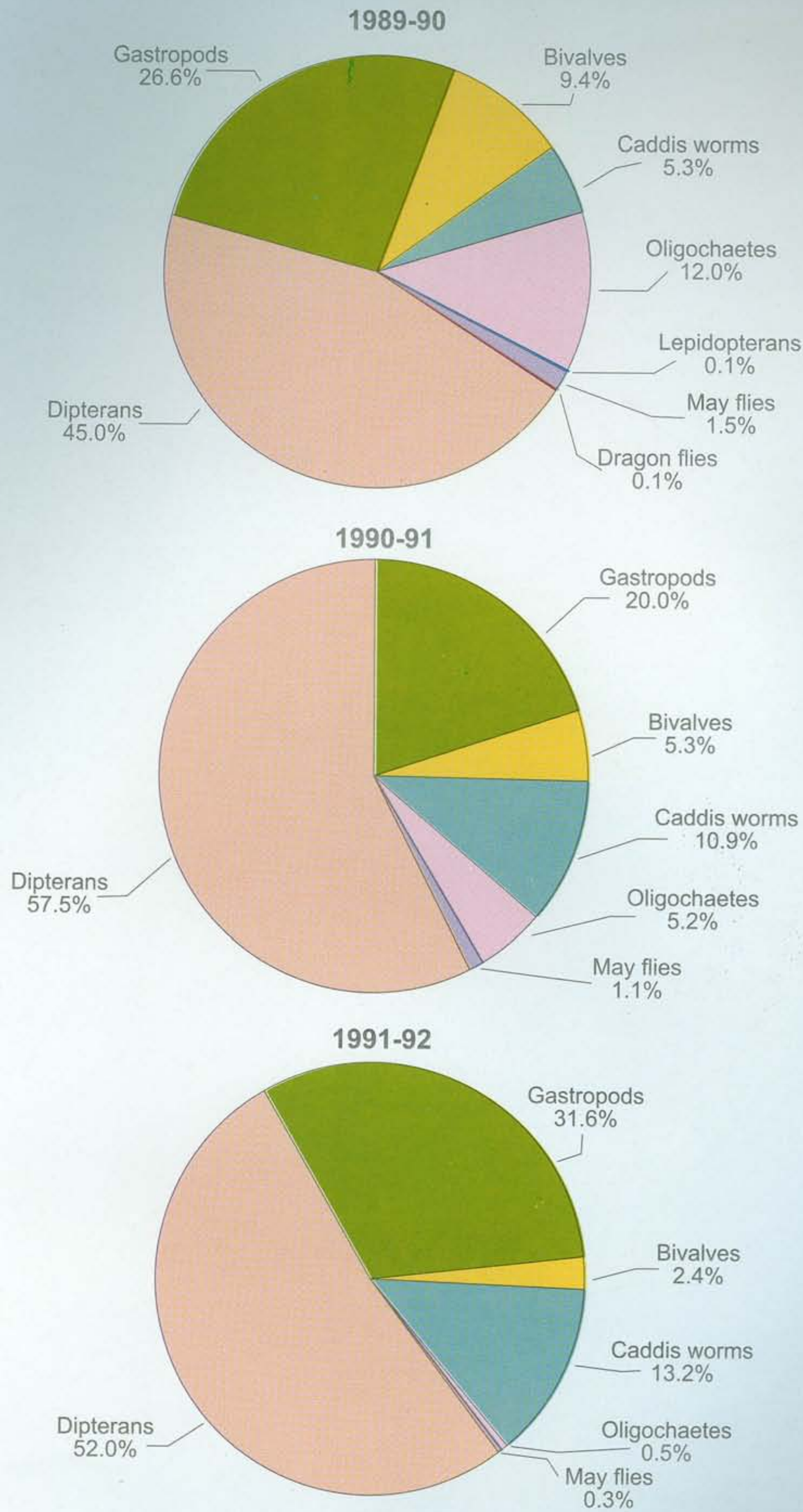


Fig. 7 : Quality composition (%) of macro-benthos of Ravishankar Sagar Reservoir

registering a distinct summer peak in June dropped down during monsoon with the effect of turbulence caused by monsoon inflow and again recouped with the peak of better magnitude in December on attainment of water stagnancy in the reservoir. In 1990-91 (105-546 nos/m^2) similar pattern of monthly distribution was noted with slight variations in availability of peaks in April, July and February. But in 1991-92 (254-845 nos/m^2) the pattern of monthly distribution was altogether different from that of previous two years. The population of macrobenthos during 1991-92, which was at low ebb in summer, progressively increased from July to October and it continued to be of high order till March with some vacillations.

10.2.2 Effect of summer reservoir water level and monsoon inflow of reservoir

During 1989-90 and 1990-91, the moderate population of macrobenthos noted in pre-monsoon period, suddenly declined in monsoon but its recoupment during post-monsoon months was not to the tune of pre-monsoon period. Against this trend, in 1991-92 the benthic population of pre-monsoon further increased during monsoons, not getting affected adversely by inflowing water and as such the population continued to be high during post-monsoon period also. The reason of not suffering dislodgement of benthic organisms in 1991-92, as happened earlier in 1989-90 and 1990-91, was that during preceding two years the summer water level of the reservoir was very low (336.14-339.68 m) and as such the incoming monsoon inflow was turbulent in action to dislocate the benthic community as a whole. On the contrary in 1991-92 the reservoir water level of summer was already very high (346.57-347.09 m) and thus the inflowing monsoon inflow was laminar in action to enter the reservoir gently without disturbing the reservoir basin and its inhabitants. Another factor of increasing benthic population in 1991-92 could be the humus soil, which was brought to the reservoir in more bulk with greater monsoon inflow of the year and serving the suitable ground for benthic organisms to live upon.

10.2.3 Sectorly variations

Studies revealed that during the two consecutive years of 1989-90 and 1990-91, while the population of lentic and intermediate sectors was comparable (357-381 nos/m^2 and 219-267 nos/m^2 respectively), the lotic sector had more concentration (609 and 388 nos/m^2 respectively). But in 1991-92 the population was uniformly distributed in all the three sectors (548-588 nos/m^2).

10.2.4 Quality composition

10.2.4.1 Numerical estimation

The macro-benthic population (by number) was chiefly constituted by Dipteran larvae (45.0-57.5%) followed by Gastropods (20.0-31.6%), Caddis worms (5.3-13.2%), Oligochaetes (0.5-12.0%), Bivalves (2.4-9.4%) and Mayflies (0.3-1.5%). Dragonfly nymphs and Lepidopterans were also encountered rarely (each 0.1%). The overall picture of three years has been shown in the pie diagram (Fig.7).

10.2.4.2 Depth-wise distribution (Usual analysis)

During the sampling period of three years, the maximum depth of water available in the reservoir was up to 20.0 m. In this depth range while the concentration of macro-benthos was good from surface to 6.0 m, it was moderate from 8.0 to 10.0 m but poor from 15.0 to 20.0 m.

10.2.4.3Depth-wise distribution (analysis as per reservoir contour level)

The analysis of macro-benthos as per the reservoir contour level was attempted for the first time in this reservoir, not done so far for any Indian reservoir. From the data based on this analysis, the benthic population at a particular water depth of the reservoir could be rightly compared for all the months of the year, which was not possible in case of usual technique of analysis (Fig. 8). Hence, this new technique was found to be more accurate than that adopted commonly.

10.2.5 Gravimetric estimation

The gravimetric estimation was also done in 1991-92. It is inferred from this estimation that though the monthly trend of population was more or less similar, there were some disparities with regard to prevalence of Dipteran larvae and Gastropods only. While the occurrence of Dipteran larvae was more than Gastropods numerically, gravimetrically those were of lesser importance.

During 1991-92 the population of macro-benthos was estimated to be 1440 kg ha^{-1} with predominance of Gastropods (65.0%) followed by Bivalves (34.5%), Caddis worms (0.3%) and Dipterans (0.2%).

10.3 Microbenthos (periphyton)

The microscopic biomass of periphyton, remaining attached to a substratum in the ecosystem, is also called 'Microbenthos'. Since the periphyton very commonly caters food to most of the fishes, the knowledge of this epiphytic community is of vital importance in study of reservoir ecology. It has been observed quite often that some of the forms, which could not be noticed in planktonic collections of the ecosystem, were available as periphyton in microbenthic community.

10.3.1 Quantitative estimation

10.3.1.1 Yearly variations

As seen from the quantitative analysis, in 1989-90 the periphyton after indicating peak in May (4782 u/cm^2) dropped down in June and gradually declined till October. Though slight recovery in the population was seen in November, the density remained poor till February-March. Among the three sectors of the reservoir, the periphyton was significantly more only in lentic sector. In view of unimodal distribution of periphyton observed in summer and that too in lentic sector, the density was adversely affected by quick water vacillations in reservoir level occurring during greater part of the year. Under these conditions, the periphytic population could crystalise in the reservoir only in May-June with lesser turbulence in water and availability of greater area of substratum in lentic sector.

In 1990-91 also the periphyton showed peak in May (354 u/cm^2) but its magnitude was very much reduced as compared to that of 1989-90. The probable ecological factors responsible for the fall in the population of periphyton could be the disturbance caused in the reservoir water by quick water vacillations, longer duration of higher water level and also the subdued solar heat of the year. The variation in reservoir water level of this year was 9.6 m against 6.2 m of 1989-90. Moreover, due to higher water level of the reservoir continued for longer time in this year, the tree trunks and boulders serving as base for periphyton were also deeply submerged under water showing lesser chances of deposition of biomass. It was interesting to note that in 1990-91 the abundance of epiphytes was more in lotic sector whereas it was denser in lentic sector earlier in 1989-90.

During 1991-92, the monthly distribution of periphyton showed peak in November (1460 u/cm^2) instead of May and its density was more than that of 1990-91 but still lower than 1989-90.

10.3.1.2 Congenial factor of abundance

The periphyton was at the highest level of concentration in 1989-90 (964 u/cm^2), which considerably decreased in 1990-91 (109 u/cm^2) and again slightly improved in 1991-92 (366 u/cm^2). While correlating the water condition of the reservoir with the abundance of periphyton, it has been observed that since the reservoir was very calm and quiet in 1989 with the availability of lowest water level (336.0 m) and reduced monsoon inflow, the population of periphyton could be built up in the least disturbance of water. The congenial factor was again available in the ecosystem but subsequently during post-monsoon period of the year the reservoir was disturbed with incoming of greater monsoon inflow. Again, during the following summer of 1991 the periphyton continued to be poor due to disturbance caused by out-flowing water through irrigation canals, which was not the case earlier during two preceding summers. However, the periphyton could set in later during post-monsoon period with the attainment of water stagnancy. The concentration of micro-benthic organisms was usually more in lentic sector of the reservoir, which apart from being the least disturbed zone of the ecosystem could also provide wider area of tree trunks and boulders for attachment of epiphytes. Thus, the study has shown that the population of periphyton in the reservoir was entirely governed by its water stagnancy and not the monsoon inflow, the factor as found applicable to the well being of plankton and macro-benthos.

10.3.2 Qualitative estimation

Bacillariophyceae (66.54-95.32%) followed by Chlorophyceae (3.97-30.98%) and Myxophyceae (0.71-2.38%) chiefly constituted the periphyton. The feeble occurrence of Dinophyceae and Xanthophyceae was recorded in 1989-90 and 1990-91 respectively (Fig.9). The different forms of periphyton encountered during the course of three years of study are listed below:

Bacillariophyceae:	*Rhopalodia, Synedra, Nitzschia, Fragilaria, Tabellaria, Cyclotella, Cymbella, Meridion, Neidium, Navicula, Diatoma, Denticula, Pinnularia nobilis, Melosira, Gomphonema, Achnanthes, Amphora, Diploneis, Campylodiscus, Eunotia, Surirella*
Chlorophyceae :	*Closteriopsis, Draparnaldiopsis, Spirogyra, Cosmarium,Microspora Chaetophora, Closterium, Zygnema, Hormidium, Ulothrix, Eudorina, Genicularia, Gonatozygon, Volvox*
Myxophyceae :	*Oscillatoria, Coelosphaerium, Tetrapedia*
Dinophyceae :	*Peridinium*
Xanthophyceae :	*Tribonema*
Euglenaceae :	*Euglena*

10.4 Macrophytes

It is well known that though the macrophytes serve as grazing grounds for some of the fishes, their excessive growth in the ecosystem is not favourable for the fish.

10.4.1 Monthly variations

In the year 1989-90 the moderate density of macrophytes recorded in September-October was very much reduced in November but abruptly increased in December-January (2130.48-2884.06 g/m^2) and slightly declined in February-March. Later in 1990-91 when the reservoir water level was very high persisting for a longer duration of 7 months from August to February, the population of macrophytes was affected very badly. Thus, in this year the macrophytes were available only for a period of 4 months from April to July showing greatest density in July (2318.84 g/m^2). Subsequently in the year 1991-92 there was a luxuriant growth in the population of macrophytes occurring abundantly (3284.78 to 11,690.87 g/m^2) throughout the reservoir all the year round. However, in 1992-93 the macrophytes were not as dense as in previous year. The moderate density of macrophytes observed in April-May, suddenly decreased in June due to inflowing water from the catchment area of the reservoir and the plants were not seen for four months from August to November. With the attainment of stagnancy in water from December, the macrophytes were found to grow again during post-monsoon period (4565.22 to 13,043.48 g/m^2).

10.4.2 Overall yearly abundance and quality

As seen from yearly average values of density of macrophytes, the population, which was moderate in 1989-90 (1399.24 g/m^2) suddenly decreased in 1990-91 (757.82 g/m^2) due to high reservoir water level. But in 1991-92 the macrophytes could grow profusely (6888.42 g/m^2) due to laminar action of monsoon inflow with least disturbance of the reservoir basin and also on account of greater intake of humus soil and availability of more nutrients. The density of macrophytes slightly declined in 1992-93 (3759.06 g/m^2) due to higher degree of water level vacillations, which was 5.4 m against 2.9 m of 1991-92. It is evident that the year 1991-92 of greater water stagnancy and lesser water vacillations was most favourable for the macrophytes.

During the course of four years of study, the submerged forms like *Hydrilla* and *Vallisneria* with some percentage of *Najas* and *Potamogeton* mainly represented the macrophytes. Further, it was noted that the plant *Chara*, the member of Chlorophyceae, was also recorded only in 1991-92 and it showed seasonal (December) recurrence in 1992-93. Thus, the repeated occurrence of *Chara* in the reservoir was of special interest in view of its calcareous nature and particularly in the context of high calcium content of the water.

11. Fish fauna

Since the commencement of studies, 48 species belonging to 15 families and 32 genera were reported from Ravishankar Sagar reservoir. The fish fauna of River Mahanadi in Raipur district was reported earlier by Hora (1940) and subsequently Jayaram and Majumdar (1976) also made the same attempt from different stretch of River Mahanadi down below from Cuttack in Orissa to Seorinarayan in Madhya Pradesh. The fish fauna of Mahanadi system thus reported from three resources has been listed in following table. The perusal of this data shows that of 48 species reported by CIFRI, 26 species were found in common with the earlier two reports and thus 22 species haye been placed on the record for the first time.

Fig. 8 : Monthly bathymetric distribution of macro-benthos in relation to reservoir water contour depth.

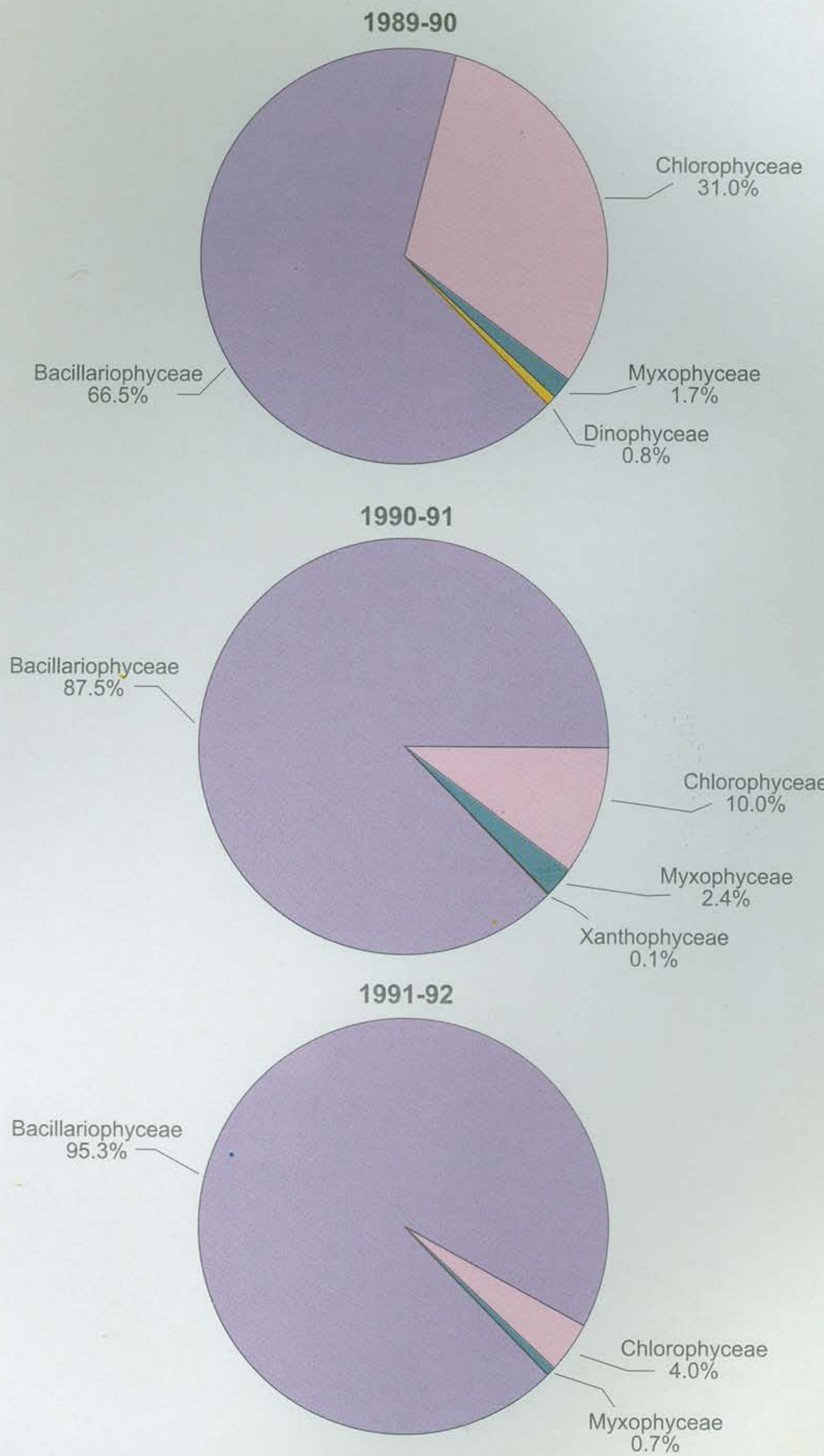


Fig. 9 : Quality composition (%) of periphyton of Ravishankar Sagar Reservoir

Fish fauna of Ravishankar Sagar reservoir and river Mahanadi

Sl. No.	Species	CIFRI Project (1987-93)	Hora (1940)	Jayaram and Majumdar (1976)	Local name
Notopteridae					
1.	*Notopterus notopterus* (Pallas)	+	_	+	Patola
Clupeidae					
2.	*Gudusia chapra* (Ham-Buch)	N	_	_	Chhuria
Cyprinidae					
3.	*Catla catla* (Ham-Buch)	+	_	+	Katla
4.	*Cirrhinus mrigala* (Ham-Buch)	N	_	_	Mrigal/Nain
5.	*Cirrhinus reba* Ham-Buch)	N	_	_	Borai
6.	*Labeo bata* (Ham-Buch)	+	_	+	Dongali
7.	*Labeo calbasu* (Ham-Buch)	N	_	_	Kannas
8.	*Labeo fimbriatus* (Bloch)	N	_	_	Potish
9.	*Labeo gonius* (Ham-Buch)	N	_	_	Kulus
10.	*Labeo rohita* (Ham-Buch)	N	_	_	Rohas
11.	*Osteobrama cotio cotio* (Ham-Buch)	N	_	_	Thewali/Kathi
12.	*Osteobrama vigorsii* (Sykes)	N	_	_	Chilati
13.	*Puntius ambassis* (Ham-Buch)	N	_	_	Jari-kotri
14.	*Puntius phutunio* (Ham-Buch)	N	_	_	Gulthi-kotri
15.	*Puntius sarana sarana* (Ham-Buch)	+	+	+	Kotra
16.	*Puntius sophore* (Ham-Buch)	+	+	+	Kotri
17.	*Puntius ticto* (Ham-Buch)	+	+	+	Gabdukotri
18.	*Chela laubuca* (Ham-Buch)	+	+	+	Norangi/ Fofasi
19.	*Salmostoma bacaila* (Ham-Buch)	+	+	+	Sirangi
20.	*Salmostoma phulo* (Ham-Buch)	N	_	_	Rangi
21.	*Amblypharyngodon mola* (Ham-Buch)	+	+	+	Mohroll
22.	*Aspidoparia morar* (Ham-Buch)	+	+	+	Baniyal/Pakla
23.	*Barilius barila* (Ham-Buch)	N	_	_	
24.	*Barilius bendelisis* (Ham-Buch)	+	+	+	
25.	*Danio devario* (Ham-Buch)	N	_	_	Amachaini
26.	*Esomus danricus* (Ham-Buch)	N	_	_	
27.	*Parluciosoma daniconius* (Ham-Buch)	+	+	+	Dandai
28.	*Garra gotyla gotyla* (Gray)	N	_	_	Butuwa
Balitoridae					
29.	*Nemacheilus* sp.	N	*	_	Ghorghus

Cobitidae					
30.	*Lepidocephalus guntea* (Ham-Buch)	N	–	–	
Bagridae					
31.	*Aorichthys aor* (Ham-Buch)	+	+	–	Singhar
32.	*Aorichthys seenghala* (Sykes)	+	–	+	Tengra
33.	*Mystus bleekeri* (Day)	N	–	–	
34.	*Mystus cavasius* (Ham-Buch)	+	+	+	Jaliya tengna
35.	*Mystus vittatus* (Bloch)	+	+	+	Gathia tengna
Siluridae					
36.	*Ompok bimaculatus* (Bloch)	+	–	+	Bolia
37.	*Wallago attu* (Schneider)	+	–	+	Padhin
Schilbeidae					
38.	*Clupisoma* sp.	N	–	–	Chikhati tengna
Belonidae					
39.	*Xenentodon cancila* (Ham-Buch)	+	+	+	Ganda
Ambassidae					
40.	*Chanda nama* (Ham-Buch)	+	–	+	Chandeni
41.	*Pseudambassis ranga* (Ham-Buch)	+	+	+	Chandeni
Nandidae					
42.	*Nandus nandus* (Ham-Buch)	+	+	–	
Mugilidae					
43.	*Rhinomugil corsula* (Ham-Buch)	+	–	+	Tetka
Gobiidae					
44.	Glossogobius giuris (Ham-Buch)	+	+	+	Khudwa
Channidae					
45.	*Channa* sp.	N	–	–	
46.	*Channa striatus* (Bloch)	N	–	–	Sanval
Mastacembelidae					
47.	*Macrognathus pancalus* (Ham-Buch)	+	+	+	Khadar bambi
48.	*Mastacembelus armatus* (Lacepede)	+	+	+	Bambi

After Talwar and Jhingran (1991).

* *Noemacheilus dayi* Hora (*Nemacheilus denisoni* dayi Hora according to Talwar and Jhingran) **N** = New record; **+** = Common record

12. Study of weed fish

The smaller variety of fish commonly known as 'Minnow fish' is also called as 'weed' or 'trash' fish. The role of such carp minnows and weed fishes in reducing the fish yield of the reservoir is well known and many of the weed fishes invariably compete with major carps for food. In addition, these trash fishes also provide forage base for the development of predatory catfish populations, which in turn affect the recruitment potential of economic carps

12.1 Fishery and exploitation

The contribution of weed fish in total fishery of Gangrel reservoir was outstanding. During the period of three years of observation (1989-90 to 1991-92), the minnow fishery was maximal in 1989-90 (42.0%), which declined in 1990-91 (31.2%) and 1991-92 (16.7%). Since the weed fishes were mainly caught by drag nets and scoop nets, their exploitation was intensive during summer months (February to June) when shore seining of drag net was favoured by the reduced water level of the reservoir, particularly in lotic sector on availability of gradually sloppy shallow banks. The drag netting was also effective in July and August when with inflowing water of monsoon the migration of weed fish to lotic sector for breeding was also more.

12.2 Yearly variations in composition

In the fish samples collected from drag net fishing of the reservoir for three years, the number of species encountered varied from 23 to 30. It was observed that *Gudusia chapra* continued to show its dominance throughout the period of three years (48.58-59.20%), but the subsequent order of importance of most of species was variable. As seen from the repeated occurrence of *Osteobrama cotio* at second position in the period of three years (11.27-15.83%), this species may also be taken as important next to *G.chapra*. It was observed that except the permanent important occurrence of *G. chapra*, the other species are bound to show variations from year to year depending on change in reservoir ecology.

12.3 Monthly variations in species composition

The studies revealed that apart from consistent overall occurrence of *G. chapra*, other species exhibited variations not only yearly but monthly also.

In 1989-90, the monthly predominance of *G. chapra* over other important species was consistently high but in June and October it was nil, while in December its contribution was exceptionally low. Next to this, other species in order of importance were *S. bacaila, A. mola, O. cotio, C. nama, P. ticto* and *P. ranga,* which indicated their percentage significantly high in December, September, March, August, October and June respectively. *P. sophore* showed predominance in May and *C. laubuca* was important in June while *P. ambassis* and *O. vigorsii* indicated their seasonal occurrence only with poor contributions in February and March.

In 1990-91 also *G. chapra* was again important with its low magnitude in October-November and being exceptionally poor in June. In order of predominance, *O cotio* ranked second which was important in June and October. Next to this, *R. corsula* indicated its seasonal importance from September to November only but in rest of the period its contribution was although nil. *C. nama* stood fourth and was important in October and February followed by *S. phulo,* which was important in January and February. Importance of *P. ranga* was more in June, followed by *S. bacaila* in October and March, *R. daniconius* in October and *E. danrica* in November. *O. vigorsii* indicated comparatively poor importance throughout the year.

In 1991-92 also *G. chapra* continued to dominate in the population throughout the year excepting July and January. *O. cotio* being second in order of importance was abundant in July and December. *C. laubuca* was also important in July and subsequently in January. *D. devario* indicated predominance in November. *P. ranga* was found to occur throughout the year but its magnitude was of low order. Among *S. phulo*, *P. ambassis* and *P. sophore* former was important in June and latter two in December respectively.

12.4 Overall composition

In all 36 species of weed fishes were encountered in the collections made during the period of three years in which *G. chapra* was the most dominating (55.85%) followed by *O.cotio* (13.06%), *C. laubuca* (3.74%), *C. nama* (3.69%), *P. ranga* (3.58%), *S. bacaila* (2.44%), *O. vigorsii* (2.32%), *S. phulo* (2.27%), *R. corsula* (2.26%), *P. ambassis* (2.06%), *P. sophore* (1.85%), *A. mola* (1.68%), *P. ticto* (1.49%) and *D. devario* (1.00%).

12.5 Food and maturity

The food study of weed fishes have shown that excepting few species, which are insectivorous, practically all were found to feed on plankton and as such their keen competition with major carps is very apparent in case of Ravishankar Sagar reservoir also. Moreover, most of the species attained maturity to breed within the reservoir and thus their recruitment and establishment in the ecosystem is very clear. The weed fishes have been classified as below with regard to their feeding habits:

No.	Classification	Species
1.	Phytoplankton feeder	*P. ambassis, P. sophore, P. ticto and A. mola*
2.	Zooplankton feeder	*O. cotio, O. vigorsii, C. nama and P. ranga*
3.	Phyto and zooplankton feeder	*G. chapra*
4.	Insectivorous	*C. laubuca, S. bacaila, S. phulo and D. devario*
5.	Mud	*R. corsula*

Though the feeding spectrum of trash fishes is wide, each species has a specific food preference. *G. chapra* feeds on phyto as well as zooplankton but *O. cotio, O. vigorsii, C. nama* and *P. ranga* appear to prefer largely zooplankton. Thus, these species are in some degrees in direct competition for food with *C. catla* and may affect the latter's productivity. Secondly some species like *P. ambassis, P. sophore, P. ticto* and *A. mola* are predominantly phytoplankton feeders and subsist on detritus and periphyton comprising blue-green algae, green algae and diatoms. These species compete to a large extent with major carps like *C. mrigala, L. rohita,* and *L. calbasu*. Under the third category comes weed fishes like *C. laubuca, S. bacaila, S. phulo* and *D. devario,* which take insects and insect larvae as dominant food, hence those species may not be considered harmful to major carps.

It has been observed remarkably that some planktonic forms though not collected directly from the reservoir along with the samples of plankton and periphyton, could be recorded in the gut contents of the weed fish. The planktonic forms noticed through the agency of weed fish are listed below:

A. Phytoplankton

Bacillariophyceae:	*Cyclotella, Gyrosigma, Diatoma, Nitzschia, Pinnularia, Tabellaria, Fragilaria, Melosira, Synedra, Navicula, Amphora, Gomphonema, Surirella, Cymbella, Rhopalodia, Neidium*
Chlorophyceae :	*Spirogyra, Pediastrum, Chlorococales, Protococcus, Closterium, Cosmarium, Scenedesmus, Eudorina, Microspora*
Myxophyceae :	*Coelosphaerium, Oscillatoria, Merismopedia*
Euglenoides :	*Euglena, Phacus*

B. Zooplankton

Cladocerans :	*Daphnia, Moina, Chydorus, Bosmina*
Copepods :	*Diaptomus, Cyclops*
Rotifers :	*Keratella, Brachionus, Asplanchna, Filinia, Monostyla, Mytilina*
Protozoans :	*Difflugia*

13. Pre-recruitment study of fish

The objective of pre-recruitment study is to find out whether the fish is breeding in the available ecological conditions and if so, to what extent and quality. The study on reservoir fish ecology is obviously placed in the context of a series of filters the fish has to pass through in the environment such as zoogeographic, environmental and biotic. The studies revealed that in this reservoir the breeding of major carps, particularly of *C. catla* and *L. rohita* is likely to be hindered due to zoogeographic barrier.

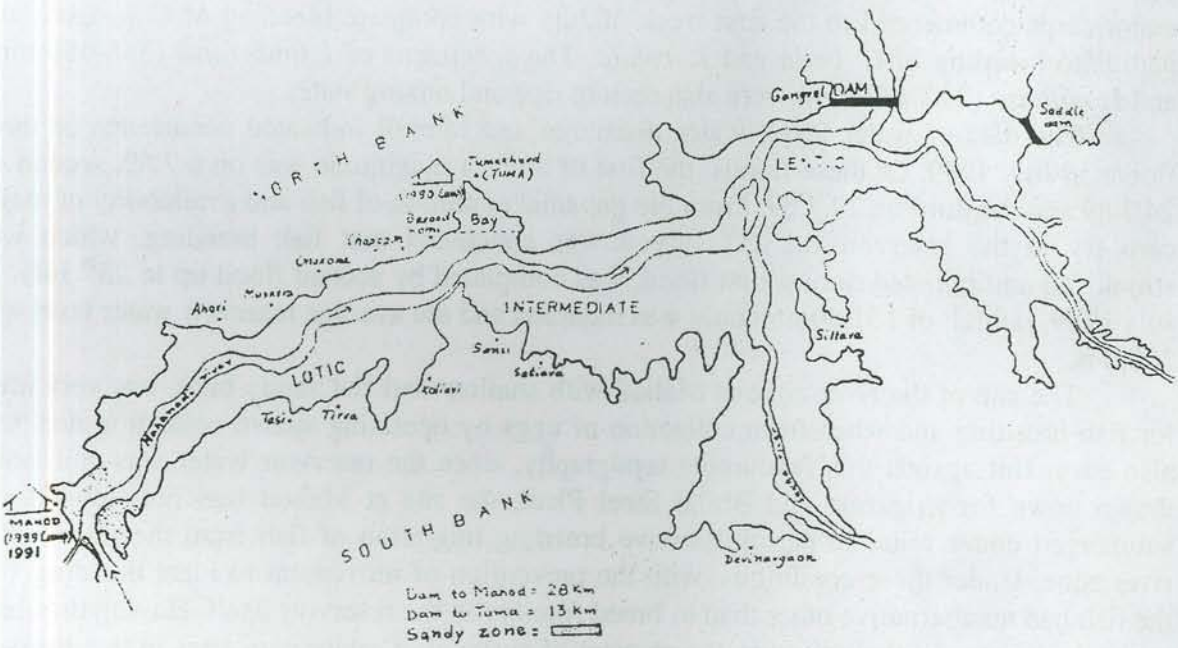


Fig. 10 Observation camps and relevant sites for pre-recruitment study

13.1 Yearly variations in recruitment

The study was conducted for four years (1989 to 1992). Considering July as the main breeding period of major carps, the observations were made in this month only.

During 1989 the site selected for this study was located in the river zone of the reservoir at village Mahod, about 40 km upstream of the dam site (Fig.9). Observations were made from 11.7.89 to 31.7.89 by operating spawn collection nets and dragnets. No spurt of fish eggs or spawn was noticed barring a few eggs and fry of undesirable fish like *P. sarana, S. bacaila* and *M. cavasius.* Some fry and fingerlings collected by drag nets along with the weed fish contained little percentage of *L. rohita* (2.49%), *L. calbasu* (0.14%) and *C. catla* (0.04%) but the entire collection, represented by 27 species of minnows, was mainly dominated by *A. mola* (36.72%), *S. bacaila* (34.20%) and *P. sophore* (10.14%). However, the occurrence of fry of *L. rohita and L. calbasu* in the collection supported the breeding of these carps in the reservoir. Moreover, the availability of fry of *C. mrigala* from intermediate sector of the reservoir at Chapgaon, 10-15 km downstream of Mahod, also gave breeding evidence of this species. In the collection from Chapgaon, *C. mrigala* (37.5%) was the most dominant followed by *C. catla* (18.7%) and *L. rohita* (12.5%). Good recruitment of *C. mrigala* is also reflected from its establishing fishery in the reservoir. This zonal variation in the occurrence of species indicated that while *C. mrigala* not requiring higher upward migration can breed in middle sector of the reservoir, *C. catla* and *L. rohita* need movement of upper extremity for breeding. The non-availability of major carps fry in the vicinity of Mahod more or less showed that for not getting the required water level/depth in the lotic zone, the upward breeding migration of major carps was not possible and hence the fish preferred to breed in the reservoir basin.

The commercial fishing of the reservoir was continued in July 1989, seeing the gonadial condition of fish from the catch of 12-13th July it was noted that the breeding of major carps commenced in the first week of July with complete breeding of *C. mrigala* and partial/no breeding of *C. catla* and *L. rohita*. The specimens of *L.fimbriatus* (345-480 mm) and *L. calbasu* (290-480 mm) were also seen in ripe and oozing state.

The data of water level, water discharge and rainfall indicated occurrence of three floods in July 1989. Of these floods, the first of highest magnitude was on 6.7.89, second on 24.7.89 and the third on 29.7.89. From the gonadial condition of fish and availability of major carp fry in the reservoir till 21st July it was concluded that fish breeding, which was stimulated and initiated during first flood, was completed by second flood up to 25th July. In July 1989, rainfall of 151.80 mm only was recorded and the average reservoir water level was 338.0 m.

The site of the river zone at Mahod with shallow and flat sandy bank was very ideal for fish breeding and wherefrom collection of eggs by operating spawn collection nets was also easy. But against this favourable topography, since the reservoir water was constantly drawn down for irrigation and Bhilai Steel Plant, the site at Mahod was not flooded and submerged under water to permit massive breeding migration of fish from the reservoir to river zone. Under these conditions, with the prevention of movement to ideal breeding site, the fish had no alternative other than to breed forcibly in the reservoir itself. Having thus bred in the deep gorge of the reservoir, the chances of survival of major carp eggs in the reservoir and particularly in the presence of dominant catfish population, can be well visualized. With such limitations the breeding success of fish in the reservoir was found conditional subject to availability of favourable breeding factors. Since the reservoir water level of 345.0 m at the dam site was reported to cause full submergence of site at Mahod under water, the breeding of fish in July 1989 with reservoir water level 338.0 m seemed to be of low order.

In 1990 the observations were made from 11.7.90 to 31.7.90 and the collection site was at village Tuma in between lotic and intermediate sector, 13 km above the dam and 15 km below Mahod. Due to precipitous bank of Tuma, the collection was restricted only to drag net operation. The day-to-day observation on gonadial condition of fish showed occurrence of oozing and ripe specimens of major carps till 21.7.90 but later the specimens were found to be in spent condition thereby indicating commencement of breeding from 22.7.90. The heavy discharge of water from the river was caused by intensive precipitation in the catchment area of the reservoir after 21.7.90. Medium carps like *L. fimbriatus, L. bata, L. gonius* and *P. sarana* were also found to breed in the reservoir.

The breeding was early in July 1989 (6.7.89) but it was delayed in July 1990 (20.7.90) for want of adequate water inflow and abrupt rise in water level. The required magnitude of water drainage (water discharge: 5696 cusecs/day) received early on 6.7.89, was prolonged till 22.7.90 (water discharge: 14163 cusecs/day). Against the four floods recorded in July 1989, only two were registered in July 1990 of which the second was of higher magnitude and longer duration. The inadequacy of water inflow from river Mahanadi to Gangrel reservoir was also attributable to low water storage of Dudhawa reservoir located 60 km upstream of Gangrel reservoir. Dudhawa was more or less emptied in summer of 1990 and as such the water from the catchment area was first utilized to fill up Dudhawa reservoir and later the surplus water was outflown to Gangrel reservoir in late July.

Phases of floods at Mahod in relation to fish breeding				
July 1989				
Flood No.	Date	Rise in level (m)	Inflow (cusecs)	Breeding
I	3.7.89	0.22	1090	No
II	6.7.89	1.20	5696	Commenced
III	24.7.89	0.34	4012	Continued
IV	29.7.89	0.68	3838	Continued
July 1990				
I	15.7.90	0.36	1947	No
II	22.7.90	0.48	14163	Commenced

While in July 1989 the breeding was observed at reservoir water level of 338 m, in July 1990 the water level at the time of breeding was 341 m. It is thus inferred that with availability of higher water level, greater submergence of lotic (river) zone during monsoon and elimination of zoogeographic barrier of the reservoir, the breeding of *C. catla* and *L. rohita* in particular, was expected to be better in July 1990 than in July 1989. But how far this breeding success can be assured with removal of good many breeders of major carps during commercial fishing of July conducted vigorously in lotic sector of the reservoir? If the breeding stock of major carps is allowed to breed in the reservoir with suspension of July fishing, their natural recruitment is expected to be good to contribute more towards building and establishment of major carp fishery.

It was observed that due to incessant rainfall in the catchment area of the reservoir on 21.7.90, its water temperature which earlier ranged from 25.0 to 28.0°c, suddenly dropped to 24.0°c with the fall in air temperature also (25.0°c) and thus the breeding of fish was induced by cooling of the environment.

It was observed in July 1990 that due to delayed breeding a few specimens of *C. catla* and *L. rohita* encountered in commercial catch from 15.7.90 to 21.7.90, were found to have plugged condition of gonads. The gonads, not finding favourable breeding conditions, were on the verge of undergoing resorption (*Atresia*), but with onset of breeding there was no recurrence of such specimens. Benson (1973) has reported the case of *'atresia'* in fish ovaries due to sudden lowering of the water level of Missouri river.

A tributary of river Mahanadi called river Sukha also joins the intermediate sector of the reservoir. The river being smaller than river Mahanadi gets lesser monsoon inflow and due to this reason migratory chances of major carps into this tributary are very remote. However, greater occurrence of *Puntius sarana* in the commercial catches of river Sukha, indicated suitability of this locality for inhabitation of *P. sarana*.

Due to early breeding of fish in1989, some fry of major carps could be collected from the reservoir in July, which was not possible in July 1990 on account of delay in breeding.

In 1991 in view of higher reservoir water level in June (346 m), the observations were made at Mahod from 11.7.91 to 9.8.91. The fish eggs could not be collected till 17.7.91 but on 18.7.91 following sudden drop in water temperature from 29.0 to 23.0°c and incoming of greater monsoon inflow (water discharge: 3522 cusecs/day), fish breeding was observed very successfully when about 20,000 eggs were collected with only 2 spawn collection nets during the spurt lasting for 4 hours only. The eggs with ova diameter ranging from 5.0 to 5.8 mm and mean modal size of 5.3 mm, on rearing were found to be mostly of *C. catla* (76.0%). The eggs were not available from 19.7.91 and the reason of sudden disappearance of egg spurt was the heavy monsoon inflow of water due to which the reservoir attained full level on 18/19.7.91 leading to opening of sluice gates. With the opening of sluice gates and causing outflow of water, the water current in the reservoir was of very high speed but despite all such unfavourable conditions, a few eggs of catla could be collected on 31.7.91 (water discharge: 45,000 cusecs/day).

The collection of drag net operation of July 1991 contributed only minnows and not major carp fry, as fairly collected in July 1989. The high water level in July and August and breeding of major carps in the river course, ruled out the possibility of collecting major carp fry from the reservoir.

The breeding observation of *C. catla* at higher reservoir water level in July 1991 (347.0 m) was successful. Since the breeding in July 1989 and 1990 was at lower water level, the breeding migration of *C. catla* to upper reaches was prevented and as such their eggs could not be collected.

During 1992 the observations on pre-recruitment were made to confirm the findings of earlier three years. The per day water discharge at Mahod was inadequate (1237 cusecs/day) till 27.7.92 against the required discharge (3000-5000 cusecs/day) and the breeding did not occur till that date. The trial netting also had no fry of major carps excepting the catch of minnows with dominance of *G. chapra* and *O. cotio*. There was a heavy rainfall on 27-28th July (118.60 mm) bringing voluminous water discharge (11457.44 to 13994.31 cusecs/day) on 28-29th July. The fish have bred very late on 28-29th July. Since the reservoir water level till the end of July was already low, the submergence of breeding site at Mahod was not possible and the fish bred in deeper zone of the reservoir. Due to considerable delay in breeding of major carps as compared to that of earlier years, 1989 (5 July), 1990 (22 July) and 1991 (18 July), the fate of breeders was uncertain in view of suspected chances of resorption of gonads. Further, due to monsoon fishing conducted earlier consecutively for three years (1989 to 1991), the stock density of major carps in the reservoir too have been reduced to give lower impact of natural recruitment.

It is concluded from the observation of four years that natural breeding of catla and rohu in Ravishankar Sagar reservoir largely depends on monsoon inflow of July and submergence of lotic sector of the reservoir water. The favourable breeding conditions may not be available regularly every year due to erratic rains and draw down of water for

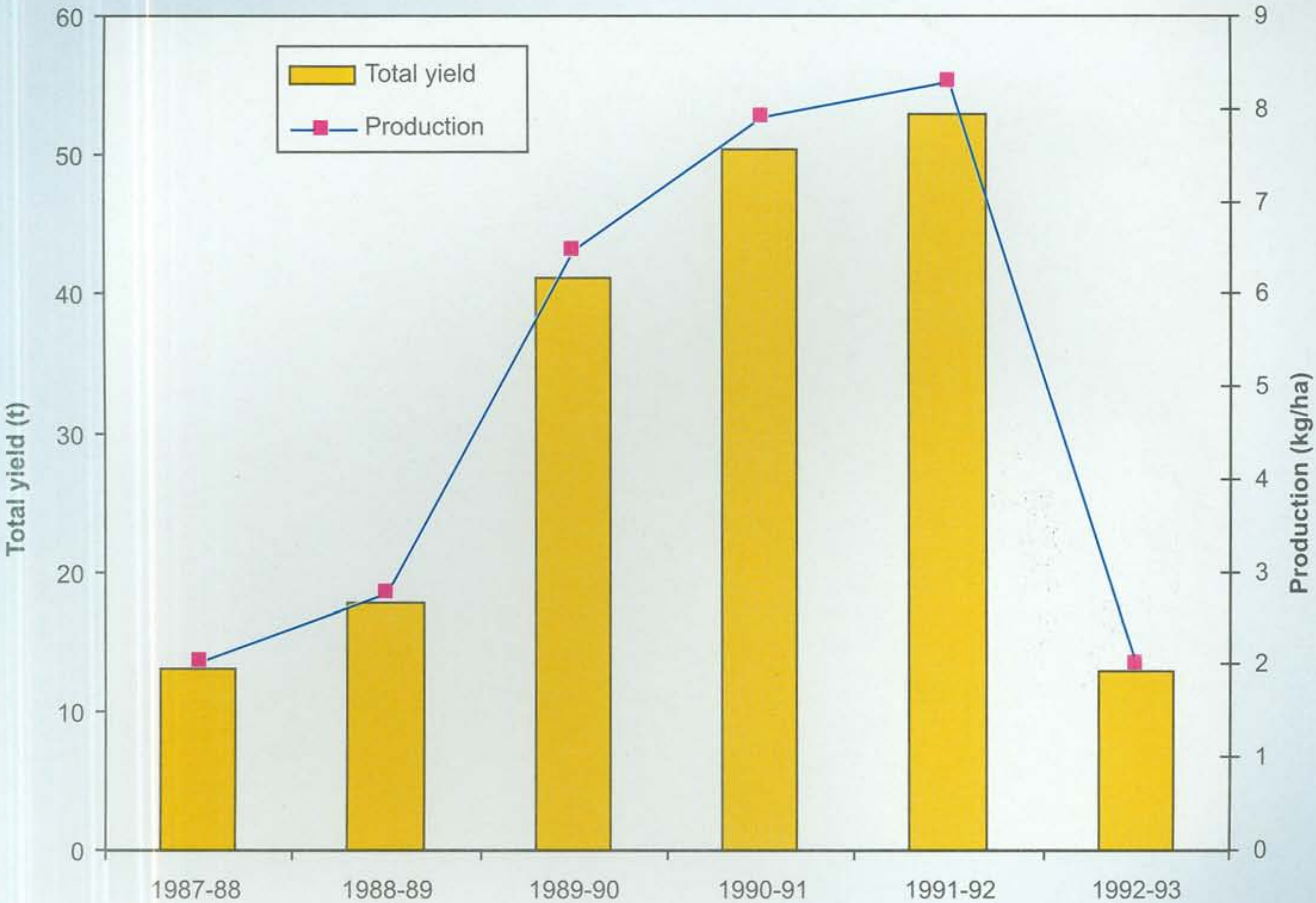


Fig. 11 : Fish yield of Ravishankar Sagar Reservoir

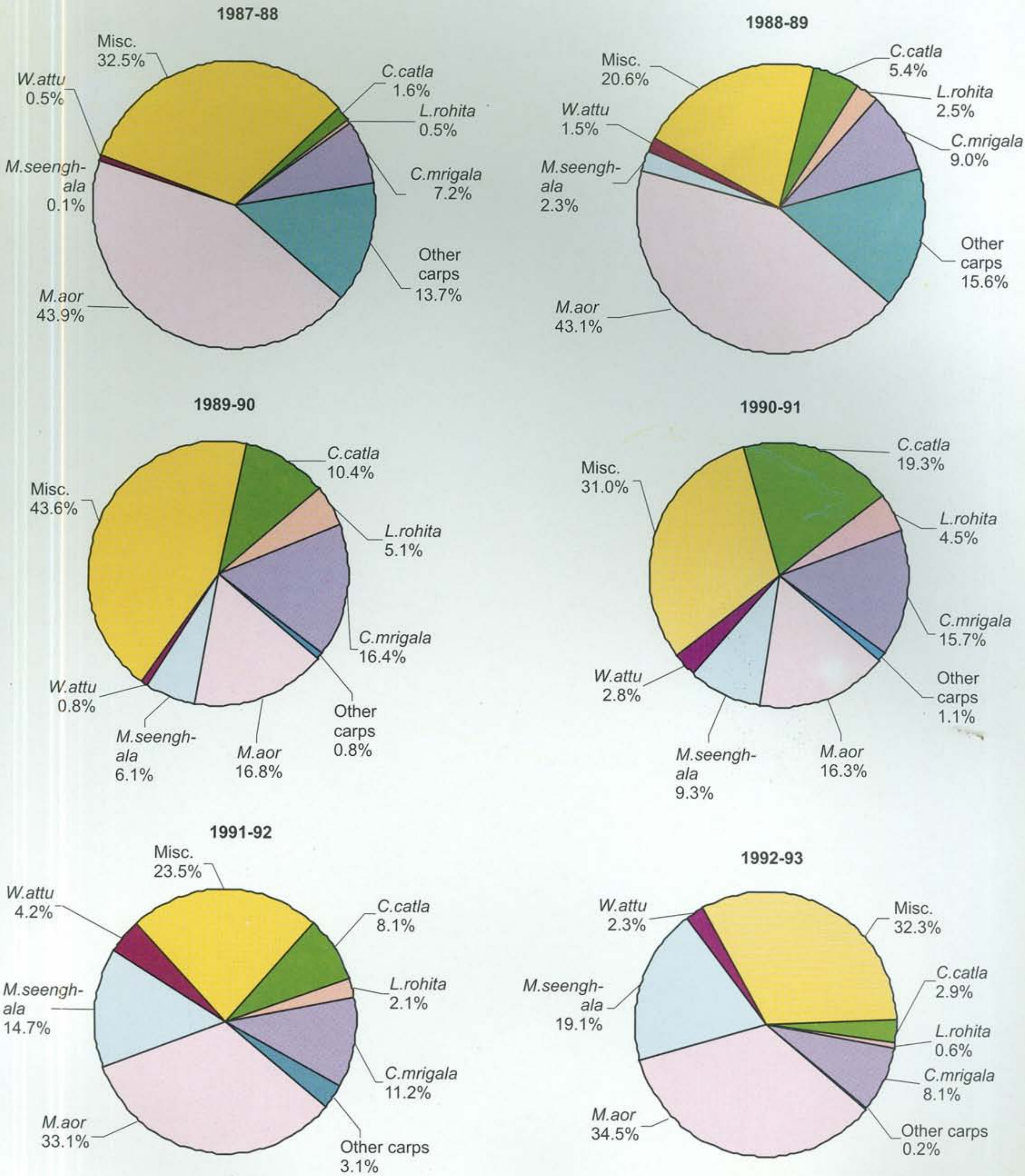


Fig. 12 : Fish catch structure of Ravishankar Sagar Reservoir

irrigation purposes. Under these circumstances, the breeding of major carps in this reservoir, excepting of mrigal, is likely to be at the stake and therefore it may suffer now and then.

14. Commercial fishery

With the completion of Ravishankar Sagar reservoir in 1978, the commercial exploitation of its fish was started after five years in 1983-84. In the first year the reservoir gave annual fish yield of 1.4 t only, which was still low in 1984-85 (0.3 t) but suddenly it increased in 1985-86 (4.2 t) and 1986-87 (9.3 t). The respective yield/ha of the reservoir during this period ranged from 0.05 kg (1984-85) to 1.47 kg (1986-87). In the fish catch, Cat-fish (34.9-68.4%) was the most important, followed by Miscellaneous fish (15.8-59.8%) and Major carps (5.3-38.5%).

Fish yield of Ravishankar Sagar reservoir

Years	Fish catch (kg)	Yield/ha (kg)	Major carps (%)	Cat-fish (%)	Miscellaneous (%)
1983-84	1407.250	0.22	7.93	65.66	26.41
1984-85	301.700	0.05	38.45	42.57	18.98
1985-86	4254.000	0.67	5.34	34.90	59.76
1986-87	9377.550	1.47	15.83	68.42	15.75

14.1 Yearly variations in fish yield

In 1987-88 the commercial fishing was conducted for 10 months observing closed season in July and August. A total fish catch of 13.0 t was yielded in this year. In 1988-89 also there was no fishing from July to September and during rest of the period fish catch of 17.7 t was landed from the reservoir. But subsequently during three years from 1989-90 to 1991-92, the fishing was conducted in July and August also though it was suspended in September (1989-90) and September-October (1990-91) but not in 1991-92. With enhancement in fishing effort, the fish catch was progressively raised from 41.2 t (1989-90) to 53.0 t (1991-92). But in 1992-93 due to some administrative difficulties of State Fisheries Corporation the fishing could be done only for six months thereby giving low fish catch of 16.7 t only.

14.2 Fishing effort and its impact on fish yield

In 1987-88 the fishing was conducted for 231 days with the operation of 14530 gillnets. In 1989-90 though the fishing span was reduced to 163 days, the operation of gill nets was more to the tune of 25554 with 75.8% increase in fishing. Subsequently in 1989-90 and 1990-91, the fishing effort was more or less comparable (247-261 days; 72234-78821 nets) with the fishing rise of (397.14-442.40%). In 1991-92 the fishing was done for maximum number of days (314) and with maximum number of nets (129552) during the course of study, increasing the fishing effort to 791.62% from that of base year (1987-88). But in 1992-93, the fishing was brought down to 125 days with the reduction in number of nets (46194) and fishing effort to 217.92%.

The perusal of data on fish yield in relation to fishing effort have already shown that increase in fish yield from 1987-88 to 1991-92 was due to enhancement of fishing intensity and particularly resorting to monsoon (July-August) fishing. Accordingly, the yield/ha of the reservoir was correspondingly raised from 2.0 to 8.0 kg. The trend could not be maintained in 1992-93 due to suspension of fishing intensity (Fig.11).

14.3 Catch-per-unit-of-effort

There was a definite correlation in fluctuations of catches and unit of effort. The unit of effort recorded to be 0.90 kg/net in 1987-88, decreased to 0.57 kg/net in 1989-90 with the increase in fishing effort thereby exhibiting indirect relationship between these variables. But the catch per day being 56.35 kg in 1987-88, progressively increased to 157.96 kg in 1989-90 clearly showing a direct relationship with fishing effort. This correlation in respect of catch per day only (204.00 kg) could be noticed in the fishing act of 1990-91 but not with regard to unit of effort, which was slightly raised (0.64 kg) despite increased fishing of the year. In 1991-92 the period of maximum fishing activity, though the unit-of-effort declined (0.41 kg) as per its expected trend but not the catch per day, which on the contrary dropped down (168.72 kg). The dislocation in yearly trend of catch per net and catch per day noted from 1991-92 gave indication of decline in the fishery which was later substantiated by the data of 1992-93 showing low order of catch per day (133.4 kg) and catch per net (0.36 kg).

14.4 Catch structure

Three broad groups mainly constituted the fish catch structure of the reservoir *viz.* Major carps, Catfishes and Miscellaneous fish. The cat-fish (23.7-55.9%) was the most important group followed by miscellaneous fish (20.6-43.7%) and major carp (11.9-40.6%) being the least. The major carp fishery progressively increased from 23.1% to 40.6% during the period 1987-88 to 1990-91 but declined to 11.9% in 1991-92 and 1992-93. The improvement in major carp fishery from 1988-89 to 1990-91 was though due to good stocking support of fish in 1986 but it was also attributed to monsoon fishing (July-August) initiated from 1989-90. But despite monsoon fishing of 1991-92, the major carp fishery started decreasing in this year which gave indication of dwindling in fishery due to subdued stocking of fish from 1989-90 to 1991-92 coupled with undertaking of monsoon fishing. The catfish population, which was at lowest ebb only in 1989-90 and 1990-91 due to over exploitation of major carps during monsoon fishing, was dominant in rest of the four years. The miscellaneous fish occurred consistently with some variations in all the six years (Fig.12).

14.4.1 Major carp fishery

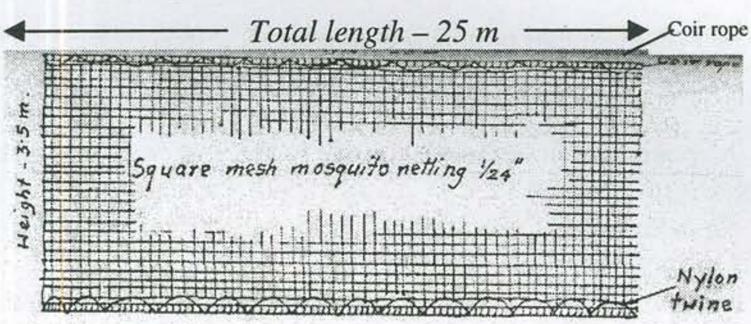
C. mrigala (7.2-16.4%) was the most important and consistent species, which progressively increased from 1987-88 (7.2%) to 1989-90 (16.4%) but started declining from 1990-91 (15.7%) to 1992-93 (8.1%). *C. catla* was the second (1.6-19.3%) in order of importance and this species also showed the same trend of yearly variations increasing from 1987-88 (1.6%) to 1990-91 (19.3%) but decreasing from 1991-92 (8.1%) to 1992-93 (2.9%). *L. rohita* was of the lowest order (0.5-5.1%) increasing from 1987-88 to 1989-90 but decreasing from 1990-91 to 1992-93 (4.5 to 0.6%). Due to greater vulnerability of major carps to monsoon fishing, mainly concentrated in lotic sector of the reservoir extensively using catla nets of bigger meshes, the major carp fishery was important during monsoons than that of winter months.

14.4.2 Catfish fishery

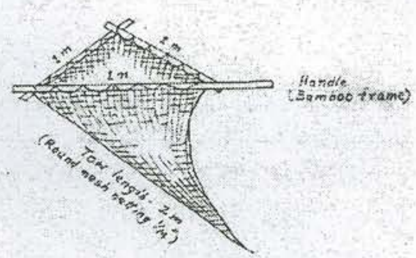
M. aor (16.3-43.8%), *M. seenghala* (0.1-19.1%) and *W. attu* (0.5-4.2%) mainly represented the catfish fishery of the reservoir. *M. aor* was important in 1987-88 and 1988-89 (43.1-43.8%) in the absence of monsoon fishing, suddenly dropped in 1989-90 and 1990-91 (16.3-16.8%) with the initiation of monsoon fishing and catching of more major carps. Subsequently in 1991-92 and 1992-93, with the reduction in major carp fishery, *M. aor* again increased (33.0-34.5%). *M. seenghala*, which was of low order in 1987-88 (0.1%) progressively increased from 1988-89 (2.3%) to 1992-93 (19.1%). Despite increase in fishing effort and catching more catfish during these years, the increasing trend in the fishery of *M. seenghala* indicated its establishment due to environmental suitability and good recruitment of this fish. *W. attu,* which was also of low magnitude in 1987-88 (0.5%) slightly increased in 1990-91 (2.8%) but sudden rise in its fishery during 1991-92 (4.2%) was attributed to long-line fishing operated only in this year.

14.4.3 Miscellaneous fishery

The catch of smaller catfishes, feather-backs, murrels, spiny eels, minor carps and weed fishes was categorized under this group. These fishes were mainly caught by drag net. During the period of six years, the miscellaneous fishery consistently ranged between 20.6% (1988-89) to 43.6% (1989-90). Being the fishery of drag net operation, it was important during January to June when the reservoir water level was reduced to facilitate easy operation of drag net in the exposed shallow marginal areas, particularly in lotic sector and a part of intermediate sector.



Drag net



Scoop net

14.5 Fish catch in relation to out-flowing reservoir water

The reservoir was regularly thrown open for commercial fishing in July-August from 1989 to 1991. During 1989 summer the reservoir had less water and moreover due to late arrival of rains, the gates of the dam were opened in August, keeping the reservoir system closed in July without out flowing the water. This condition favoured successful fishing operations in lotic sector to catch more brood fish during July fishing of 1989 and 1990. On the contrary in 1991, with early rainfall in June the reservoir attained full level in July and sluice gates were opened earlier on 18.7.91. Due to outflow of water from the reservoir, the water current was so fast that fishing operation was not possible after 19.7.91 and many gill nets were drifted down to the dam. Thus, the commercial fishing in July 1991 was adversely affected and the high fish yield obtained during the period 1.7.91 to 18.7.91 (catch/day: 516.0 kg; catch/net: 0.75 kg), suddenly decreased from 19.7.91 onwards (catch/day: 240 kg;

catch/net: 0.44 kg). This reservoir condition did not exist earlier in July 1989 and 1990 due to which the catches were high during the closed reservoir water system.

14.6 Major carp fishery during three monsoons

C. mrigala ranked first followed by *C. catla* and *L. rohita* during three monsoons, which again supported the well-established Mrigal fishery of the reservoir. Major carp fishery was at its peak in 1990 (12651.5 kg) with lowest fishing pressure but decreased in 1991 (5808.6 kg) with increased fishing, going further down below the level of 1989 (6950.7 kg). The debacle was severe in *C. catla* as seen from its greater occurrence in 1990 (1169 nos; 8488.0 kg), which was very reduced in 1991 (337 nos; 2721.55 kg).

14.7 Maximum Sustainable Yield (MSY) and Optimum Fishing Effort (fmsy)

The reservoir gave an annual fish yield of 13.0 t (1987-88) to 50.4 t (1990-91) with the production of 2.0 to 8.0 kg/ha/A on the average water spread of the reservoir (6380 ha). The increase in fish yield during this period was mainly due to enhanced fishing, when the fishing effort was raised to the tune of 80% in 1990-91 over that of the base year 1987-88.

The yearly data of fishing effort (number of nets) and catch/net (kg) when analysed statistically using Schaefer's model, the Ravishankar Sagar reservoir was found capable to give maximum sustainable yield (MSY) of 52 t with optimum fishing effort (fmsy) of 120000 gill nets in a year. The equation of this model was expressed as:

$$\mathbf{Y(i)/f(i) = 0.88 + (-0.0037)\,f(i)}$$

Where Y (i)/f (i) = catch per net (kg); f (i) = number of nets operated; 0.88 = intercept (a); -0.0037 = slope (b)

Using the above equation, the equilibrium annual fish yield of the reservoir was also calculated. The yield gradually increased from 16.12 t to 52.38 t with increase in fishing effort from 20000 to 120000 nets but later the fish catch declined despite enhanced fishing. Hence, this can be taken as the level of maximum sustainable yield.

As seen from the data for the period excluding the monsoon fishing (1989-90 and 1990-91), the reservoir was found to give MSY of 28 t per annum only with 55000 nets. The comparison of annual yield of two fishing acts has clearly indicated that MSY of 50 t per annum will be achieved only by virtue of monsoon fishing and not otherwise, which is not the right policy as per fishery legislation. Therefore, efforts have to be made to increase the fish yield to the desired level, observing July-August as closed season. The major carp fishery may topple down if the right management practices such as banning monsoon fishing and adequate stocking with catla and rohu are not monitored as required.

14.8 Long-line fishing

During monsoon fishing of 1991, the long lines using fish as bait were operated for the first time since the commencement of exploitation of reservoir fishery. A total of 35 units of long lines operation were conducted during 13.7.91 to 23.7.91, which yielded a catch of 133.650 kg. Each line was operated during night hours only. The catch per line was calculated to be 3.8 kg. *W. attu* (66.0%), *M. seenghala* (31.3%) and *M. aor* (2.7%) were predominant. This gear appeared to be effective to catch *W. attu*, which was not properly caught by gill net fishing.

14.9 Modes of commercial fishing

The commercial fishing of Ravishankar Sagar reservoir was executed by three modes as below:

14.9.1 Departmental fishing

During 1987-88 to 1992-93, this fishing was conducted for 2 years in 1987-88 and again 1990-91. It was entirely processed by the State Fisheries Corporation with the help of fishermen co-operative societies of the reservoir. While the exploitation of fish from the reservoir was done by the fishermen, the transportation of fish to Calcutta and its marketing was with the State Fisheries Corporation. The Corporation paid labour charges as wages to the fishermen for catching the fish. The rate of wages (per kg) were differently ear-marked as per category of fish shown below:

i. Major carps (Catla, Rohu and Mrigal)	: Rs. 22=25
ii. Local major (Cat fishes)	: Rs. 20=00
iii. Minor carps	: Rs. 15=00
iv. Minnow fish	: Rs. 03=50

14.9.2 Royalty fishing

This fishing was done for three years during 1988-89, 1989-90 and 1991-92. In this fishing also the fish was caught by the fishermen and co-operative societies but with the involvement of Fish Contractor who paid royalty to the State Fisheries Corporation and wages to the fishermen. The Contractor did the transportation and marketing of fish. The royalty rates (per kg) fixed by the Corporation varied as shown below but the rates of wages were same as for departmental fishing.

Royalty fishing rates (Rs./Kg)

Years	Catla	Other IMC	Local major	Local minor	Minnows
1988-89	21.25	14.55	12.25	4.25	3.00
1989-90	17.10	13.50	12.05	6.50	3.50
1991-92	12.00	12.00	5.00	4.00	-

14.9.3 Lifting contract

It was adopted in 1992-93. The fishing contract of the reservoir was given to Fish Contractor for one year on lease basis. The Contractor was permitted to catch the fish from the reservoir with local fishermen of co-operative societies paying fishing wages to them. The Contractor paid a lump-sum amount to the Corporation towards the cost of fish as per tenders and also did transportation and marketing of fish. The rates of wages (per kg) paid by the Contractor were:

Catla (above 5 kg)	Rs. 27=50
Catla (3-5 kg)	Rs. 25=00
Catla and other major carps below 3 kg	Rs. 21=00
Local major	Rs. 18=00
Local minor	Rs. 10=00
Minnows	Rs. 04=00

There are three local Fishermen Co-operative Societies in the periphery of the reservoir with total number of their members being 121.

15. Fish Biology

15.1 Major carps

Biological studies on length-weight relationship, relative condition, age and food of major carps were carried out.

15.1.1 Length-weight relationship

The length-weight relationships of major carps are expressed as:

C. catla	**Log W = 5.7662 + 3.3371 log L (r = 0.99)**
L. rohita	**Log W = 4.9512 + 2.9954 log L (r = 0.99)**
C. mrigala	**Log W = 4.9444 + 2.9876 log L (r = 0.99)**
L. calbasu	**Log W = 5.8532 + 3.3405 log L (r = 0.99)**

Where W = weight of fish (g) and L = length of fish (mm)

15.1.2 Relative condition

The relative condition (K_n) of major carps showed that condition of *C. mrigala* was the best (0.9-1.3) followed by *C. catla* (0.9-1.2), *L. rohita* (0.9-1.1) and *L. calbasu* (0.9-1.1). The condition of *C. catla* was good during II and III years of age (550-700 mm) but later it declined. The downward inflexion in relative condition of fish fairly agreed with their lengths-at-maturity thereby indicating that the fall in 'condition' was due to spawning strain.

15.1.3 Age

The statistical relationships between fish and scale lengths of *C. catla, L. rohita* and *C. mrigala* were as below:

C. catla	**Y = 0.6065 + 0.0296 X (r = 0.93)**
L. rohita	**Y = 4.5221 + 0.0315 X (r = 0.92)**
C. mrigala	**Y = 0.2741 + 0.0214 X (r = 0.95)**

It was observed that against the normal order of growth trend of major carps like catla-rohu-mrigal, the annual instantaneous growth rate and increment of *C. mrigala* in respect of Ravishankar Sagar reservoir was slightly better than that of *L. rohita* particularly at later stage of life.

15.1.4 Length-frequency of major carps

15.1.4.1 *Catla catla*

The fish measured from 312-1012 mm in total length showing modal lengths at 587, 712, 762, 812 and 887 mm with peak at 712 mm. Against these six modes, the lengths-at-ages of fish back-calculated from scale study were 557 mm (1+), 700 mm (2+), 793 mm (3+) and 879 mm (4+), which more or less corroborated with modal lengths of length-frequency analysis. The reservoir was stocked with greater quantity of catla seed (60%) in 1987-88 and as seen from the modal lengths of 712, 762, 812 and 887 mm representing age groups of 2+ to 4+ years, the stocking impact of catla was reflected moderately in its fishery.

15.1.4.2 *Labeo rohita*

It was measured in the size range of 362 to 782 mm with the modal lengths at 400, 480, 542, 587, 617, 692 and 740 mm with peak at 587 mm. Against the eight modes, the lengths-at-ages calculated from scale analysis of fish were 407 mm (1+), 493 mm (2+) and 563 mm (3+), which also more or less agreed with first three modal lengths. The stocking of *L. rohita* in the reservoir was good and consistent from 1987-88 to 1992-93 (30-50%). But rohu fishery is not being built up in the reservoir as seen from its poor stock strength.

15.1.4.3 *Cirrhinus mrigala*

The size range 360 to 840 mm in the commercial landings represented it with seven modal components at 437, 527, 587, 617 and 707 mm (peak at 527 mm) against the lengths-at-ages of 365, 462 and 548 mm (3+) calculated by scale analysis. The stocking of mrigal in the reservoir was most subdued from 1987-88 to 1992-93 (12-40%) as compared to that of catla and rohu but still its reflection in the fishery was better (2+-7+ years). Apart from occurrence of seven modal lengths of fish, the negative skew ness of length-frequency was more pronounced in *C. mrigala*, which clearly supported its good recruitment in the reservoir to contribute to a sustained fishery by natural course. Hence, it does not require much stocking support as needed for catla and rohu.

15.1.4.4 *Labeo calbasu*

This species though not stocked so far in Ravishankar Sagar reservoir forms an insignificant fishery in the reservoir. But the occurrence of five modal lengths in length-frequency analysis of this species at 327, 357, 387, 417 and 477 mm (peak at 357 mm) was quite interesting.

15.1.5 Food of major carps

Due to lean fishery of major carps and difficulty in getting their specimens, the rectal contents of major carps were collected and analysed, which gave fairly good idea about subsistence of fish on planktonic food available in the reservoir. Some planktonic forms, which were either absent or poorly represented in the samples of plankton and periphyton collected from the reservoir, showed their existence and availability in the analysis of rectal contents. Thus, the food like mud/sand and organic detritus consumed by the major carps of Ravishankar Sagar reservoir had diversity in its composition. The occurrence of phytoplankton was more in *C. mrigala, L. rohita, L. calbasu* and zooplankton in *C. catla*.

15.2 Catfishes

15.2.1 *Mystus aor*

This was the most important species of the reservoir forming an outstanding fishery with its contribution ranging from 16.3 to 43.8% during six years (1987-88 to 1992-93). Low percentage of *M. aor* was only due to catching of major carps during monsoon fishing of 2-3 years otherwise the species was consistent throughout. Length-frequency of fish showed that it was represented by the size range 233-593 mm with modal lengths at 323, 383, 473 and 503 mm (peak at 503 mm). The modal lengths when compared with those reported from other water bodies with ages, indicate that probably the above size groups belong to 1 to 4 years of age. As seen from condition of feed and gastrosomatic index, the feeding intensity of fish was high from January to March but declined in April-January due to breeding activity. During this period the relative condition (K_n) of fish was also low. Most of the mature fish were found in the size range of 430-545 mm, which indicated that the fish attained first maturity at 430 mm, as supported by low relative condition of fish at this length. The fish bred in intermediate and lotic sectors of the reservoir constructing pits. It mainly subsisted on fish (94.0%) followed by prawns (5.5%) and insects (0.5%). The length-weight relationship of the species can be expressed as:

$$\text{Log W} = 5.1222 + 3.0007 \log L \ (r = 0.99)$$

15.2.2 *Mystus seenghala*

The abundance of this species was much lesser than that of *M. aor*, consisting 2.3 to 19.3% in the total fishery of six years. But progressive improvement in its fishery from 1987-88 to 1992-93 clearly showed that the species is establishing well in the reservoir to form a sustained fishery due to its good recruitment. Moreover, the intensive fishing of this species has also affected its fishery. The wider size range of 412 to 1062 mm showing modal lengths at 462, 662 and 812 mm (peak at 662 mm) represented its commercial catch. As seen from maturing state of gonads and higher values of gonado-somatic index in April-June, this species also seemed to breed in summer months. The fry of *M. seenghala* were also collected from the reservoir quite often during monsoons to support its breeding in the reservoir. The fish mainly fed on fish (94.3%) with some preference for prawns (5.7%) also. The fish diet was composed of weed fishes like *G. chapra, Puntius* spp, *O. cotio* and *Ambassis* spp and thus the presence of this fish and *M. aor* in reservoir may be called a must and means of biological control of undesirable fishes competing with major carps in space and food. The length-weight relationship of the fish can be expressed as:

$$\text{Log W} = 4.9837 + 2.9078 \log L \ (r = 0.99)$$

The relative condition of fish, which suddenly declined in the size range of 450-800 mm, later improved.

15.3 Fecundity

During the course of study, the fecundity of following fishes was worked out: -

Sl. No.	Species	Number	Size range (mm)	Number of eggs	Ova-diameter (mm)
1.	*C. mrigala*	4	540-675	263467-790417	1.3-1.4
2.	*L. fimbriatus*	1	430	160833	1.0-1.5
3.	*L. gonius*	1	350	138000	1.0-1.3
4.	*P. sarana*	3	260-270	88160-133589	1.0-1.5
5.	*O. vigorsii*	11	200-260	6500-28000	0.3-0.9
6.	*N. notopterus*	2	255-288	1090-1940	0.5-3.5
7.	*M. aor*	2	500-530	30600-59400	0.4-1.2
8.	*M. cavasius*	10	130-180	9000-19800	0.6-0.8
9.	*O. bimaculatus*	1	250	19210	0.7-1.0

15.4 Biology of *Gudusia chapra*

The biological aspects of the fish like length-weight relationship, relative condition, breeding periodicity and age/growth were studied.

15.4.1 Length-weight relationship

The length-weight equation is expressed as:

$$\mathbf{Log\ W = -6.436 + 3.321\ log\ L\ (r = 0.99)}$$

Where L is the length of fish (mm) and W is the weight of fish (mg). In this formula the exponential value (3.321) distinctly deviated from the cube law and when ascertained by t-test, it was found to be significant at 5% showing allometric growth pattern.

15.4.2 Relative condition

The relative condition of fish (K_n), which was moderate in smaller fish (20-25 mm), suddenly dropped down in fish of 30 mm and then progressively increased from the fish of 40 mm to attain peak in 60 mm. The fall in K_n value at 30 mm may be attributed to some change in feeding. Again, there was a steep fall in the condition of fish growing over 60 mm, which continued till attaining size of 75 mm. The values of relative condition indicated recoupments at 80, 105 and 125 mm but with the troughs at 95 and 115 mm.

15.4.3 Breeding periodicity

Studies revealed that 0-group was noticeable first in February-March and then again in July. Though the fish started breeding in Feb-Mar, the main breeding was in July because the indication of recruitment was not very clear from April to June as was pronounced later from August to November throughout the period of 4 months. Thus, the fish appeared to breed intermittently for a period of 8-9 months from February to October, as also documented by Jhingran (1977) from April to October in the same species of river Ganga at Allahabad.

15.4.4 Age

Going by first breeding of fish observed in February as witnessed from presence of 0-age group at 30 mm, this month was taken as the base line for tracing out the position of different modes representing the age groups during February to January of succeeding year. The 0-group was noticeable in February-March, though not seen in April and June, could be located in May and from July to February so as to attain modal length of 50 mm in first year till next March. The I-year age group was thus similarly seen in May and from July to November and January-February thereby to gain length of 60 mm in March during II-year of age. Subsequently, the II-year age group was distinctly observed continuously from April to November, January-February to be reflected in March as III-year age group at 70 mm. Accordingly, the progression of IV, V and VI-years age groups of fish could also be traced out from February to March at 80, 90 and 100 mm respectively.

The sharp downward inflexion in relative condition was at 60 mm length of fish, which seemed to be the size at first maturity of fish in third year of age. The most of the fishes growing over 60-70 mm in length were in maturing state, which supports the inference drawn on the maturity of fish in III year. Moreover, the inflexion points showing diminution of Kn with increasing length as recorded at 50, 75, 95 and 110 mm length, more or less corresponded to II to VI years of age groups in view of subdued condition of fish due to spawning strain. Thus, the 0 to VI year age groups of *G. chapra* from Ravishankar Sagar reservoir were represented by smaller size range (30-100 mm). The age groups of 0 to VIII of the same species reported from river Ganga by Jhingran (1977) belonged to higher size range (50-200 mm). The maximum size of *G. chapra* recorded from Ravishankar Sagar reservoir was 130 mm against that of 200 mm from river Ganga. This also supports the view that *G. chapra* from Ravishankar Sagar reservoir being a smaller fish may represent a different stock.

15.4.5 Food

The food studied for three size groups of fish in the available size range of 20-130 mm did not show any marked variation in the diet excepting minor changes occurring through seasonal variations in fish food availability in the reservoir. On the whole *G. chapra* was found to feed more on phytoplankton (66.1%) than zooplankton (33.9%) despite greater abundance of the latter in the reservoir. This amply supports the availability of phytoplanktonic niche in the ecosystem, being used by the fishes though its reflection in the samples of plankton collected from the reservoir is of very low order. The diversified planktonic food of *G.chapra* was found to consist of *Euglena, Phacus* (Euglenoids), *Closterium, Pediastrum, Eudorina, Cosmarium, Scenedesmus, Spirogyra, Microspora, Protococcus* (Chlorophyceae), *Fragilaria, Pinnularia, Diatoma, Navicula, Synedra, Cyclotella, Amphora, Gyrosigma, Melosira, Tabellaria, Rhopalodia, Nitzschia* (Bacillariophyceae), *Coelosphaerium, Oscillatoria* (Myxophyceae), *Daphnia, Chydorus, Bosmina* (Cladocera), *Diaptomus, Cyclops* (Copepoda), *Brachionus, Keratella, Monostyla, Asplanchna, Mytilina, Filinia* (Rotifera) *and Difflugia* (Protozoa).

16. Stock strengthening of major carps

The data pertaining to stocking of fish in the reservoir with size range, number/ha and quality composition for 1986-87 to 1992-93 are given below:

Year	Fish stocking (lakhs)	Nos/ha	Size range (mm)	Species composition (%)		
				Catla	Rohu	Mrigal
1986-87	20.00	315	30-100	10.0	50.0	40.0
1987-88	12.00	190	30-100	60.0	30.0	10.0
1988-89	15.00	235	30-100	25.0	50.0	25.0
1989-90	7.24	115	30-100	21.7	37.0	41.3
1990-91	6.00	95	30-100	46.0	42.0	12.0
1991-92	7.59	120	30-100	39.4	46.5	14.1
1992-93	18.35	290	30-100	28.5	52.9	18.6
Total/Av.	**86.18**	**195**		**33.0**	**44.0**	**23.0**

16.1 Stocking by State Fisheries

The above table shows the details of fish seed stocking done by the State Fisheries Corporation in the reservoir during 1986-87 to 1992-93. During this period a total of 86,18,000 fish seed (30-100 mm) with yearly average of 195 nos/ha in the ratio of Catla 3: Rohu 5: Mrigal 2 was stocked in the reservoir. As seen from the above data, the stocking rate was good ranging from 190 to 315 nos/ha during 1986-87 to 1988-89, which certainly helped in boosting the fishery to the tune of 53.0 t in 1991-92 after 3-4 years. This was clearer after seeing the ages of catla, rohu and mrigal encountered in commercial catch. While *C. catla* with modal length of 712 mm was of 3 years, *L. rohita* and *C. mrigala* with modal lengths of 587 and 572 mm respectively were of 4 years of age. Though the stocking rate was reduced during 1989-90 to 1991-92 (95 to 120 nos/ha), it was raised to 290 nos/ha subsequently in 1992-93. It is evident that despite giving more emphasis on stocking of *L. rohita*, this fish could not contribute to fishery so well as it should, probably not finding the reservoir suitable. Against this background, *C. mrigala* though getting less stocking support as compared to that of *C. catla* and *L. rohita* formed a consistent important fishery among major carps, obviously on account of its good recruitment in the reservoir adjusting with its low water level during monsoons.

16.2 Proposed stocking rate and ratio

Based on the studies of primary production, the reservoir is capable to give potential fish yield of 160 t/A (= 25 kg/ha/A). The growth studies of major carps have revealed that annual average growth of IMC in this reservoir was found to 400 g in first year of age of fish, like Catla 660 g; Rohu 375 g; Mrigal 165 g. Therefore, in order to achieve fish production of 25 kg/ha/A with estimated annual growth rate of IMC (0.4 kg), according to Huet's formula:

$$\text{Stocking of fish} = \frac{\text{Potential fish yield of reservoir (kg)}}{\text{Annual growth of fish (kg)}} + \text{Allowance}$$

The reservoir basically needs 65 fingerlings to be stocked per hectare annually. But looking to the heavy loss of fish through escapement from irrigation canals and predation with dominance of catfish population of the reservoir, additional allowance of 100% ought to be given to compensate the loss. Thus, 130 say 150 fingerlings/ha/A are required. On the productive area of the reservoir (6380 ha), the total requirement of fish seed comes to 957000 fingerlings per annum.

17. General remarks

Ravishankar Sagar reservoir being an Irrigation Project is like a storehouse to supply water for irrigation and Bhilai Steel Plant as and when required, particularly all the year round. Accordingly, the reservoir may be called as an intermediary balancing water body to receive water from its catchment area and Dudhawa reservoir located 60 km upstream across the same river system-Mahanadi, and to feed down below for irrigation and Bhilai Steel Plant. Owing to these characteristics, with the process of inflowing and out-flowing of water continuing for a greater part of the year, the reservoir is almost a fluviatile lake having no water stagnancy with lesser period of water retention. The reservoir obviously has certain limitations in giving optimum fish yield. Against this scenario of fish production potentiality of Ravishankar Sagar reservoir, Dudhawa reservoir located above in the same agro-climatic conditions is highly productive (80 kg/ha/A) only on account of its greater period of water retention. However, the man-made reservoirs basically constructed for irrigation and hydel purposes, may not care for fish unless they are handled properly on right direction for managing their fishery wealth. The Ravishankar Sagar reservoir with all its limitations and drawbacks is one such reservoir from fisheries point of view.

18. Benefits of the study

Prior to the inception of research project of CIFRI in 1986, no authentic scientific information was available for this reservoir. The benefits to be accrued are as below:

1. The ecological studies of the reservoir covering its morphometric, climatic, physico-chemical and biological parameters, which altogether govern the fish productivity, would help in better management and development of fishery of this reservoir.

2. The fish yield of the reservoir, which was low earlier before the commencement of study (2.0 kg/ha/A), was raised later (8.0 kg/ha/A) through enhanced fishing as recommended by the project. Maximum Sustainable Yield (MSY) of the reservoir with optimum fishing effort (fmsy) was determined and confirmed in 1991-92.

3. Exact fish catch structure of the reservoir, excepting the composition of major carps only, which was not known earlier, was analysed later only to show that the reservoir has predominant population of cat-fish and minnows with establishing fishery of *C. mrigala* but not of *C. catla* and *L. rohita*, which are to be built up with stocking support only.

4. Studies revealed that recruitment of *M. aor* and *M. seenghala* was good in the reservoir, which is a matter of great concern for the State Fisheries managers to gear up the efforts to control the population of predatory fish with intensive fishing. Efficacy of long-line fishing for eradication of *W. attu* was also pointed out.

5. The analysis of weed fishes, particularly of *G. chapra*, has shown consistent dominance of the species in the fishery, due to its prolonged active breeding in the reservoir and exhibiting rivalry with major carps in feeding on plankton.

6. The list of 48 fish species of the reservoir was documented, which was not on record earlier.

7. It was only through the analysis of some biotic communities like macro-benthos and macrophytes, the fact of their non-utilization as fish food, was brought in lime-light to know stocking of suitable fish in the reservoir for this purpose.

8. The pre-recruitment study of fish clearly indicated that breeding of major carps, particularly of *C. catla* and *L. rohita*, is mainly governed by adequate monsoon inflow of water in July. Moreover, the breeding success of these two species is dependent on submergence of their breeding grounds in lotic sector (river zone) of the reservoir with availability of higher reservoir water level (347 m).

9. The policy of continuing commercial fishing in July and August adopted by State Fisheries Corporation for three consecutive monsoons was erratic, which was pointed out to State Fisheries showing its adverse effects on major carp fishery of 1991-92.

10. It was only after knowing breeding limitations of *C. catla* and *L. rohita* in the reservoir, escapement of their fry through irrigation canals, predatory and adverse effects on major carps with dominant population of cat-fish and minnows and lastly the carrying capacity (potential fish yield) of the reservoir, the stocking of major carps in desired ratio and combination of three species was suggested to State Fisheries.

19. Recommendations

❖ During 1987-88 to 1992-93, the maximum fish catch from Ravishankar Sagar reservoir was obtained in 1991-92 (53 t). Earlier 1987-88 and 1988-89 the fish yield was low (13-17 t) due to subdued fishing effort and hence the State Fisheries Corporation were suggested to enhance the fishing effort from 1989-90 gradually to the maximum tune of 129552 gill nets and thereby to get increased fish yield from 41 t (1989-90) to 53 t (1991-92). But this act also included monsoon fishing (July-August), which was not a right step because it entailed heavy loss of major carp breeders. The hike in major carp fishery from 1989-90 was mainly due to July fishing *i.e.* catching brood fish from lotic sector of the reservoir during their breeding migration. The pre-recruitment studies of fish clearly showed that catla and rohu are being deprived of their successful breeding for want of attainment of required reservoir water level (above 345 m) in July. Despite this fact the monsoon fishing continued in 1990 and 1991 with the result the fishery after attaining peak in 1991-92 started declining in 1992-93, in which catla was the most sufferer. Moreover, in July 1991 the opening of dam gates further triggered the loss of fish catch when gill net operation was ineffective due to fast current of water. In view of these observations, the State Fisheries Corporation was advised to desist from monsoon fishing for the benefit of fishery and accordingly the monsoon fishing was banned in 1992-93. It should be strictly followed in future also.

- ❖ During 1190-91, the Maximum Sustainable Yield (MSY) of the reservoir was calculated to be 50 t/A with optimum fishing effort (fmsy) of 120000-gill nets, which was subsequently confirmed in 1991-92. Since the estimated MSY was inclusive of monsoon fishing, which was not desired and hence with monthly fish catch of 3 to 4 tonnes during the course of 10 months, the reservoir is expected to yield 30-40 tonnes of fish of fish with present stock density. Presently only 0.33% of potential fish yield (160 t/A) is being harvested thereby to give further scope of increasing fish yield.

- ❖ As per the Irrigation authorities, attainment of full reservoir water level (FRL) in Ravishankar Sagar reservoir was erratic in the past 15 years after its construction in 1978. The reservoir was full only twice in 1986 and 1991. The attainment of FRL with good rainfall was not a regular feature in Ravishankar Sagar reservoir and reduced reservoir water level with poor monsoon inflow in July may recur time to time. The pre-recruitment studies of fish have shown that breeding success of catla and rohu was not good in July 1989 and 1990 at low water levels and as such their breeding failure may be a common factor in this reservoir. Under these circumstances, regular stocking with greater emphasis on catla and rohu is essential.

- ❖ The reservoir was stocked with fish seed adequately @ 300 nos/ha/A (about 15 lakhs) in the year 1986-87 and the impact of this stocking was subsequently seen on the fishery after 4-5 years attaining peak production in 1991-92 (53 t). But the above rate of stocking was not maintained later from 1989-90 to 1991-92 (100 nos/ha/A). Therefore, the State Fisheries Corporation was suggested to revive the stocking rate to original level. Based on studies of potential fish yield, annual growth rate of major carps and escapement/predation allowance, the reservoir at least needs regular stocking of 150 fingerlings (100-150 mm) per hectare per year with greater emphasis on catla and rohu followed by mrigal.

- ❖ The study on bottom biota of the reservoir indicated abundance of molluscs and dipteran larvae in the ecosystem but any fish present in the reservoir is not utilizing these food niches. The molluscs when not being eaten up may be causing unfavourable proliferation in the reservoir. In order to control this process, to use the biomass as food and to add to fish productivity of the reservoir, it is worthwhile to introduce *Pangasius pangasius* in the reservoir. Further, the dipteran larvae may also be utilized with stocking of *Cyprinus carpio (communis).* Apart from utilization of dipteran larvae, *C. carpio* would also make use of the macrophytes abundantly in the reservoir as egg collectors while breeding easily in captivity. Going by the occurrence of macrophytes (*Hydrilla* and *Vallisneria)* in the reservoir, Tor mahseer (*Tor tor)* may also be inoculated for utilization of macrophytes and molluscs as food. Looking to establishment of *C. mrigala* in the reservoir, the bottom dwelling fishes may thrive well in such water body with lesser chances of escapement through irrigation canals.

- ❖ The analysis of fish catch of the reservoir clearly indicated overall dominance of Minnow fish (weed fishes) with preponderance of *G. chapra*, which not only breeds profusely in the reservoir but also keenly competes with major carps in feeding. Since the minnows are effectively caught by dragnets only, the fishermen should be encouraged to use these nets with greater frequency for eradication of minnows, particularly during reduced water level of summer months (February-June) in lotic sector, facilitated through availability of more suitable fishing areas. The State Fisheries should keep the royalty rate of minnow fishing, at low level as an incentive to fishermen to catch more fish of this category.

- ❖ Fisheries of *M. seenghala* and *M. aor* are establishing well in the reservoir with their good recruitment and their presence in the ecosystem to some extent is of course beneficial to major carp fishery in view of their voracious feeding on minnow fish, which also needs to be kept under control. Even though with this plus point of *Mystus,* their populations have to be brought down to reduce predatory effect on major carp fishery through intensive fishing.

- ❖ In 1991-92, the long lines were operated in the reservoir for the first time. The analysis of their catches revealed their efficacy for *W. attu* (70%) and *M. seenghala* (30%) and scope of paying dividends to reservoir fishery through their continual operation. Therefore, the operation of long lines may also be attempted for commercial exploitation of fish.

- ❖ In order to reduce the chances of escapement of fish fry/fingerlings through irrigation canals, it is recommended to undertake stocking programme in December-January and that too in the bays and coves of intermediate sector. The bays and coves may also be useful for cage/pen culture practices. Further, the village ponds located in the periphery of the reservoir, may also be searched as an asset to fry rearing having no fish farm at the reservoir.

- ❖ As seen from the cluster of tree trunks, being more in intermediate sector, the reservoir was not reclaimed in this respect. Proper attention should be given to this developmental measure also to clear off trunks from the intermediate sector, the place of main fishing thrust having more fish, which remains unexploited due to difficulty in gill net operation.

Ravishankar Sagar Reservoir

Irrigation Canal

Downstream

Limno-chemical sampling

Macro-benthos collection
(Inset : Gastropods)

Plankton collection

Fish landing centre

Specimens of *Mystus* spp.
(Inset : long-line fishing)

Catch of minnow fish

Operation of spawn collection net

Collection of fish eggs from shooting net

Storing of fish eggs in hapa
(Inset : Fish eggs)