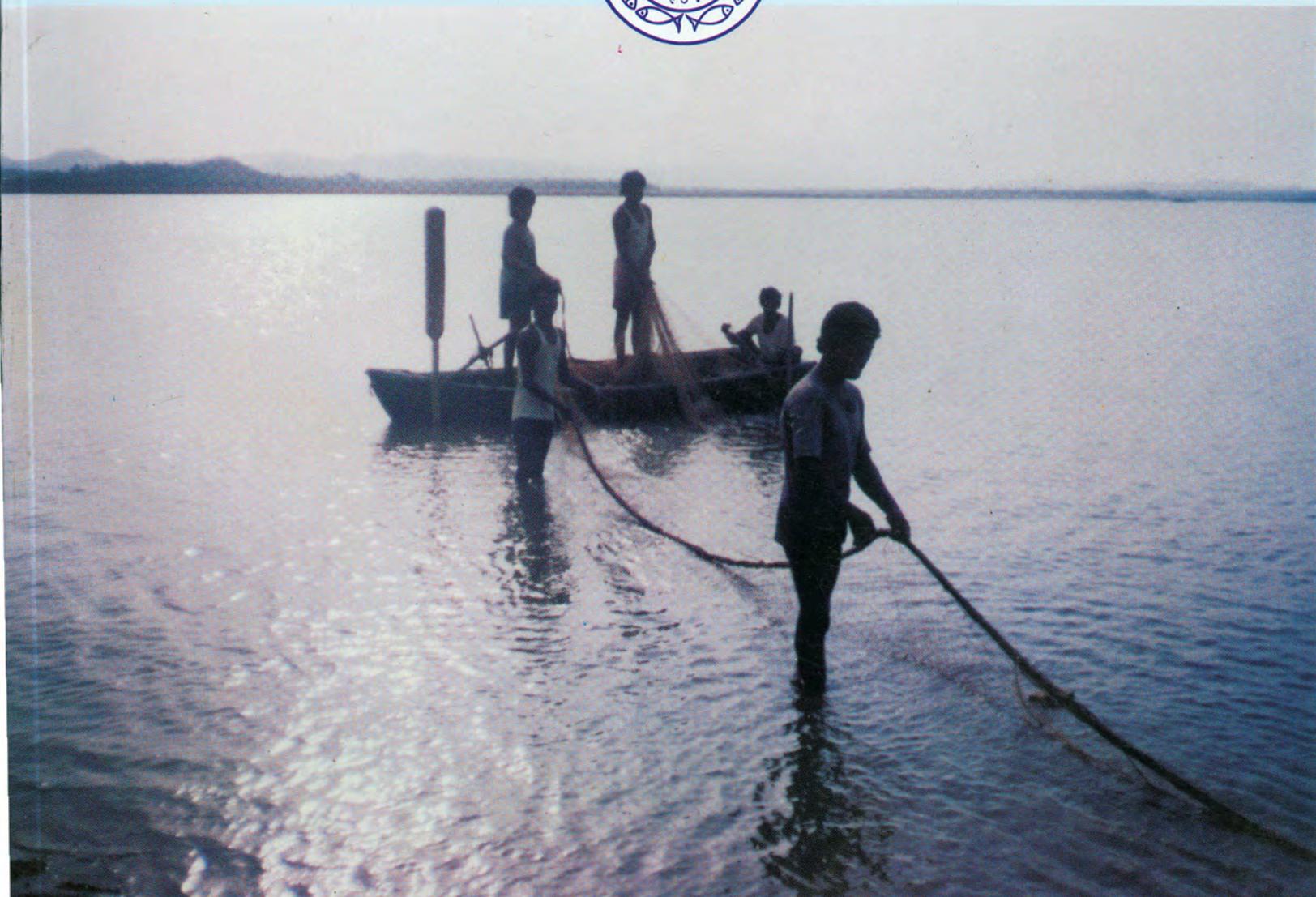


Ecology and Fisheries of Tawa Reservoir **(Hoshangabad, Madhya Pradesh)**

**Central Inland Capture Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore-743 101 West Bengal**



Ecology and Fisheries of Tawa Reservoir (Hoshangabad, Madhya Pradesh)

Foreword

ISSN 0970-616 X

The reservoir is a vital resource with immense potential of increasing the inland fish production. The Central Inland Capture Fisheries Research Institute, Barrackpore, West Bengal, has been entrusted with the responsibility of conducting research and development in inland fisheries.

2000

It is a pleasure to record the excellent cooperation received from the M.P. Inland Fisheries Corporation during the investigation. Thanks are due to the Inland Fisheries Division of Irrigation Department, Tawaragar and Tawa Matoga, Hoshangabad, Madhya Pradesh for their kind assistance and facilities provided during the investigation.



Bull. No.100

September 2000

Central Inland Capture Fisheries Research Institute

(Indian Council of Agricultural Research)

Barrackpore-743 101 West Bengal

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ISSN 0970-616 X

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2000

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Composed at : **The Project Monitoring &
Documentation Section**
CIFRI, Barrackpore

Assistance : Sefali Biswas
Cover design : P. Dasgupta

Published by : **The Director, CIFRI, Barrackpore**

Printed at : M/S. Toparts Private Ltd.
8/2, Dr. Biresh Guha Street
Calcutta-700017

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2. Smt. C. Sainani, Principal Scientist	Associate

Foreword

The reservoirs in India constitute a vast resource with immense potential of increasing the inland fish production of the country. Unfortunately fisheries development in reservoir on scientific lines has been neglected. CIFRI in order to develop a national reservoir data base initiated studies in various reservoirs situated in different states of India. Tawa reservoir in Hoshangabad, Madhya Pradesh was taken up for intensive investigation by scientists of CIFRI for a number of years. The valuable data generated is documented in the publication.

I am hopeful it will greatly help in understanding the ecology and population dynamics of the reservoir for its scientific management.

I place on record the excellent corporation received from the M.P. State Fisheries Corporation during the investigation. Thanks are due to the RBC Division of Irrigation Department, Tawanagar and Tawa Matsya Sangh, Kesla.

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Director

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Acknowledgements

Constant help, guidance and encouragement by Dr. M. Sinha, Director, CIFRI, Barrackpore is acknowledged with deep sense of gratitude. Thanks are due to Dr. M. Ramakrishniah, Head, Reservoir Division, Bangalore for going through the manuscript critically and suggesting valuable improvement.

Excellent co-operation received from the M.P. State Fisheries Corporation during the entire course of this investigation is thankfully acknowledged.

Thanks are due to the RBC Division of Irrigation Department, Tawanagar for providing the reservoir and other related data.

Tawa Matsya Sangh, Kesla deserves sincere thanks to allow to record the fish landings and provide relevant information.

The help from Dr. D. Nath, Shri M. M. Bagchi, Sr. Scientist, Barrackpore, Dr. A. K. Das, Scientist (Sr. Scale) Bangalore and Shri Alok Sarkar, Tech. Officer, Guwahati in analysing soil and water samples also needs a special mention. The help rendered by Dr. R.K. Manna (Scientist), Bangalore in preparing tables and figures of the bulletin is also gratefully acknowledged. The services rendered by Smt. G. Vinodalakshmi, Stenographer and Shri K. Manjhi, Sr. Clerk in typing draft manuscript are also placed on record with due appreciation.

CONTENTS

	<i>Page No.</i>
Introduction	1
The reservoir and its morphometry	1
Sampling programme	3
Meteorological observations	3
Hydrology	3
Soil and water quality	3
Stratification	4
Primary production	4
Biotic communities	5
Plankton	5
Macro-benthos	5
Periphyton	6
Macrophytes	6
Fish fauna	7
Fishery	8
Craft and gear	8
Landing centres	8
Fishing effort	9
Fish catch and catch composition	9
Biology of fish	10
Length-weight relationship and condition of major carps	10
Age / size group in the catch	10
Observations on breeding and recruitment	11
Impact of stocking on fish yield	12
Maximum sustainable yield (MSY) and optimum fishing effort (fmsy)	12
Management	12
Productivity status and fish yield potential	14
Recommendations	15
Summary	16

Introduction

With the coming up of large number of river valley projects, a number of artificial impoundments have been formed throughout the country which have great potential to increase the inland fish production. Madhya Pradesh is one of the States having rich water resources. The two main West flowing rivers, the Narmada and the Tapti, the East flowing Mahanadi and several tributaries of Ganga (Chambal, Betwa, Sone) and Godavari (Wainganga) flow through the State. All these rivers have been tapped for various purposes like irrigation, power generation, flood control, storage and navigation. The State has a water spread of 4.6 lakhs ha under reservoirs, the highest in the country and is likely to go up further with the formation of proposed Narmada Sagar reservoir (91,348 ha). The small and medium reservoirs account for 74% of the area. Total fish production from the reservoirs in M.P. during 1989-90 was 2000 t (9 kg ha^{-1}) which was raised to 6484 t (22 kg ha^{-1}) in 1994-95. The low yield is mainly attributed among others to inadequate stocking, wrong species mix and low size of the stocking material. There is immense scope of increasing reservoir fish production of the State through scientific management. In this context it is imperative to have a correct understanding of reservoir ecology and trophic dynamics to arrive at right selection of species for stocking and rational exploitation.

Tawa reservoir (Narmada system) was taken up by Hoshangabad centre of CIFRI for detailed investigations with the objective of studying the ecology and production dynamics in order to evolve management strategies to obtain maximum sustainable fish yield. The data so generated would also contribute to the reservoir data base which in turn will be useful for the management and conservation of fish stocks in open water bodies. The investigations were carried out from 1994 to 1998.

The reservoir and its morphometry

The river Tawa is an important tributary at the river Narmada. It rises from the Satpura range of hills (Mahadeo hills) at an elevation of 762.5 m and runs 169 km before joining the Narmada, upstream of Hoshangabad. Tawa river has a major tributary, the Denwa. The catchment is deeply wooded and receives the highest rainfall in the Narmada valley.

Tawa reservoir ($22^{\circ} 30' 40'' \text{ N}$ and $77^{\circ} 58' 30'' \text{ E}$) was constructed in 1975 across the river Tawa, 823 meters down the confluence of rivers Tawa and Denwa. It is one of the large reservoirs of Madhya Pradesh with a water spread of 20,055 ha. It extends to 32 km in length and the maximum breadth is 22 km. The length of Denwa stretch is 26 km, the maximum breadth being 8 km. The reservoir is moderately deep (mean depth 11 m). The ratio of catchment to reservoir area, an index of allochthonous inputs, is low at 30, part of the catchment intercepted. The shore development index (5.6) indicates that shore line is moderately irregular. The volume development index (0.73) being less than 1 shows convex nature of the basin. Both the indices are positive for production. The flushing rate (annual inflow/storage capacity) is moderate (1.7). The details of the dam and reservoir are given below.

Project site	:	Near village Ranipur, 33 km from Itarsi and 50 km from Hoshangabad
Year of commencement	:	1968
Year of completion	:	I phase 1975, II phase 1979
Purpose	:	Irrigation (3.32 lakh ha), industrial use (water supply to Ordnance factory at Itarsi) and power generation (13.5 MW).

Dam Details

Masonry

Length of dam (m)	:	237.74
Spillway gates	:	13 Nos. radial gates (50' x 40')
Max. height of dam above the lowest foundation level (m)	:	57.91
Top width of spillway bridge (m)	:	6.68

Earthen

Length of left dam (m)	:	690.37
Length of right dam (m)	:	521.21
Saddle I (m)	:	182.88
Saddle II (m)	:	182.88
Max. height above lowest point (m)	:	7.62

Reservoir details

Water spread (ha) at FRL (A)	:	20,055
Water spread (ha) at DSL	:	4425
Average area (ha)	:	12,240
Catchment area (km ²) (C)	:	5982.90
C/A	:	30
FRL (m) above msl	:	355.40
DSL (m) above msl	:	334.24
Max. water level (m)	:	356.69
Top level of dam (m)	:	359.66
Sill level (m) above msl	:	310.90
Gross storage capacity (10 ⁶ m ³)	:	2311.54
Live storage capacity (10 ⁶ m ³)	:	2048.81
Capacity at DSL (10 ⁶ m ³)	:	262.73
Maximum depth (m)	:	45
Mean depth (m)	:	11
Shore line (km)	:	280
Shore development	:	5.58
Volume development	:	0.73
Annual inflow (10 ⁶ m ³)	:	3915
Flushing rate	:	1.7

Sampling programme

The entire reservoir was arbitrarily divided into three sectors viz., lentic, intermediate and lotic. Two sampling centres have been chosen on each sector, one on the East Bank and the other on the West Bank and one centre on the Denwa stretch (Fig.1). Samples were collected from all the centres covering the entire reservoir. Standard methods were followed for collection and analyses of samples. The studies cover morphometric and hydrographic features, soil and water quality, carbon production, biotic communities, fish yield and fishing effort, biology of fish and breeding and recruitment. The fish seed stocking data supplied by the Fisheries Corporation have been analysed in relation to yield of different species.

Meteorological observations

The air temperature at the reservoir site varied from 22.4° (Dec) to 34.0°C (Sep). Rainfall around catchment of the reservoir (Jun-Oct) during past 26 years (1972-1997) ranged from 378 (1989) to 1679 mm (1976) with an average of 1100 mm. The maximum precipitation (67%) occurs during July and August.

Hydrology

The data on hydrology of Tawa are given in Table 1. Following the monsoons, water levels increased from July and attained FRL in September-October. Low levels generally occurred during April-June. The fluctuations in water level were high in 1996-97 (12.6 m) and 1997-98 (12.4 m) as compared to other years (6.8-10.8 m). Peak inflows occurred during July-September (87.5%). In last 24 years (1975-76 to 1998-99), the annual inflow ranged from 1893 million m³ (87-88) to 7847 million m³ (94-95), the average being 3915 million m³. The average inflow during the study period (94-95 to 97-98) was 4359 million m³. The maximum water was outflow during August-September and November-March. The flushing rate (1.7) is moderate. The annual evaporation loss fluctuated in a narrow range 231-260 million m³.

According to the recent studies of Verma and Biseria (1995) the siltation during the last two decades have altered the basin topography facilitating the operation of dragged gears in some areas. It also appears to have affected the breeding grounds of some fishes.

Soil and water quality

The data on soil quality are presented in Table 2. Soil texture varied from loam sand to sandy clay loam during pre and post-monsoon periods respectively. pH varied from slightly acidic (6.2) to alkaline (8.0) state. Organic carbon (0.17-1.57%; av. 0.63%) and total nitrogen (0.025-0.064%; av. 0.047%) showed low to high range, while available phosphorus (0.2-1.8 mg/100 g; av. 0.57 mg/100 g) was low. Free calcium carbonate (0.5-6.5%; av. 2.9%) was moderate. Monsoon months recorded relatively high values of specific conductivity, organic carbon, available phosphorus, total nitrogen and calcium carbonate.

Soil chemistry indicated that the productivity of the reservoir could be low to medium. The water temperature ranged from 22° (Dec) to 33°C. The Secchi depth ranged from 17 cm (Jul) to 228 cm (Jan), average being 107 cm. Transparency showed sectoral and seasonal variation. It was low in lotic sector (57 cm) and relatively high in lentic (125 cm) and Denwa (127 cm) sectors. The euphotic zone varied from 1.4 to 3.2 m (av. 2.7 m). The extinction coefficient exhibited indirect relationship with water transparency and euphotic zone and varied from 0.013 to 0.030 (Fig. 2).

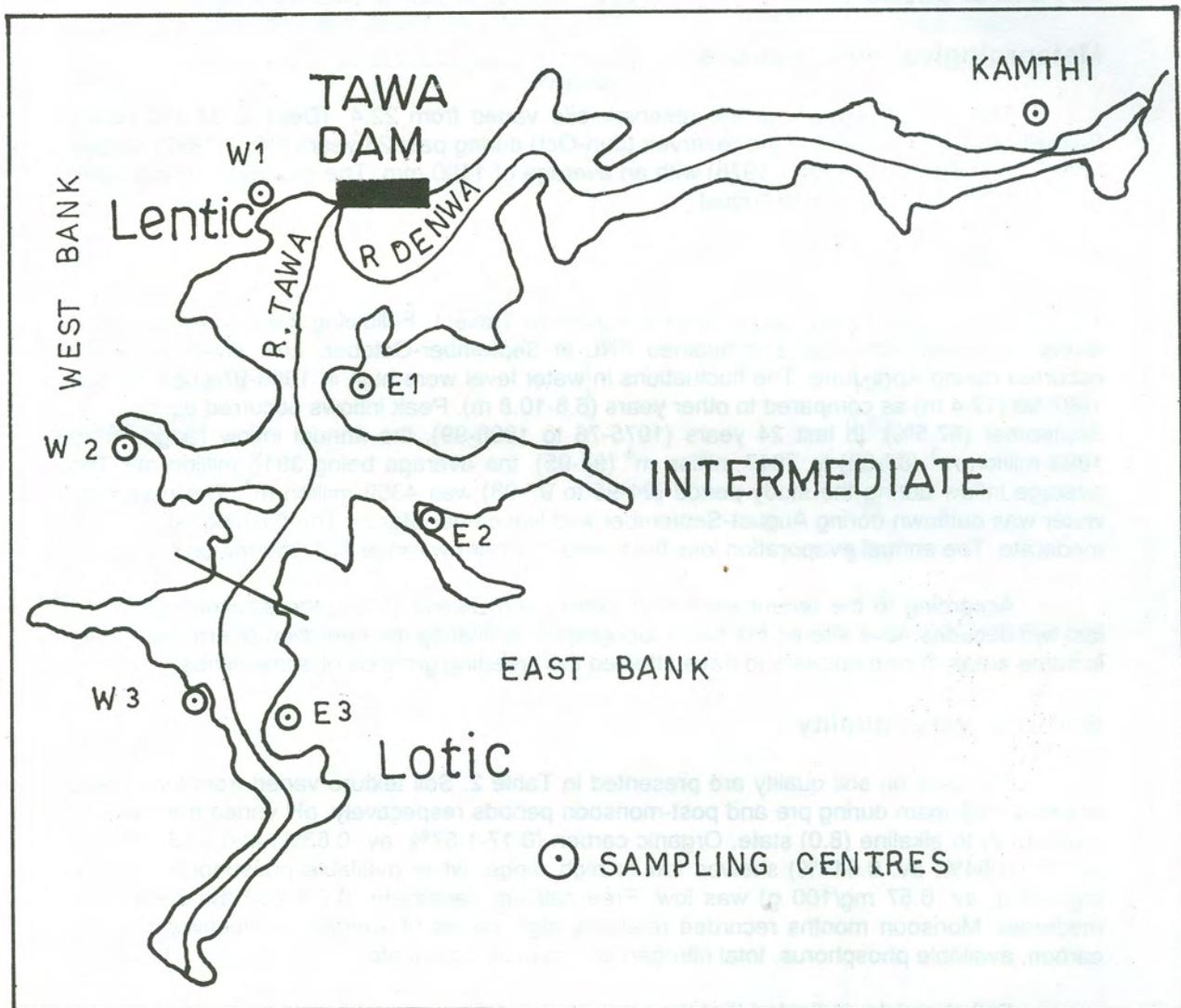


Fig. 1. Map of Tawa Reservoir showing sampling centres



Tawa dam



A view of Tawa reservoir near dam site



Lotic sector of Tawa reservoir



Down-stream of Tawa dam



Tawa hydro-electric dam



Tawa hydro-electric power plant showing its canal

Table 1. Hydrographic features of Tawa reservoir

Parameter	1994-95	1995-96	1996-97	1997-98	1998-99
Water level (m) (asl)	344.5 - 355.2	344.9 - 355.3	342.7 - 355.3	342.9 - 355.3	348.5 - 355.3
Gross capacity (10 ⁶ m ³)	873.9 - 2276.0	907.5 - 2299.7	720.6 - 2311.5	731.4 - 2311.5	1255.6 - 2311.5
Annual inflow (10 ⁶ m ³)	7847	2525	2359	4706	4248
Annual outflow (10 ⁶ m ³)	8027	2558	2007	3830	4168
Evaporation loss (10 ⁶ m ³)	238	231	232	260	252

Table 2. Physical and chemical characteristics of soil of Tawa reservoir (1995-97)

<i>Physical</i>	
Sand (%)	66
Silt (%)	18
Clay (%)	16
Texture	Sandy clay loam
<i>Chemical</i>	
pH	7.1
Sp. cond. (mScm ⁻¹)	190
Org. carbon (%)	0.63
Total N (%)	0.047
C/N ratio	13
Avail. P (mg/100 g)	0.57
Free CaCO ₃ (%)	2.9

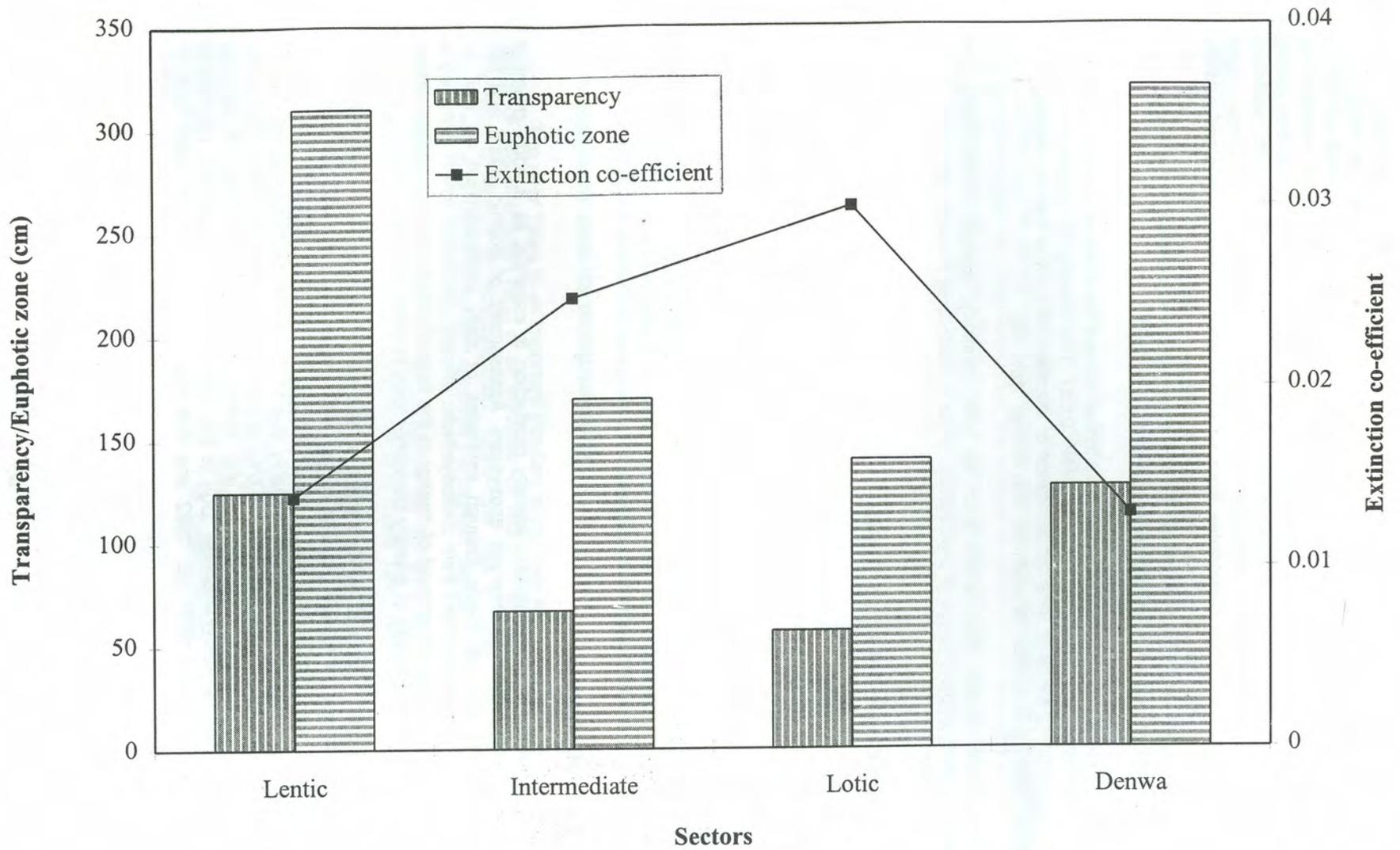


Fig. 2. Sectoral variation in transparency showing euphotic zone and extinction co-efficient of Tawa reservoir (1995-97)

The water quality did not exhibit any distinct sectoral variation and hence the average values of all the sectors are shown in Table 3. pH varied from neutral to alkaline range (7.1-9.2; av. 8.3). Dissolved oxygen (5.8-8.4; av. 7.1 mg^l⁻¹) was fairly high at surface with 50 to 98% of saturation. Higher DO values were recorded during pre and post-monsoon months and low values during monsoons due to turbidity. Free carbon dioxide was recorded only during post-monsoon upto 8 mg^l⁻¹. Total alkalinity (46-97; av. 72 mg^l⁻¹) was moderate with maximum values occurring in pre-monsoon months and minimum during monsoons. Bicarbonate ranged from 46-85 mg^l⁻¹ (av. 66) and carbonates from nil to 18 mg^l⁻¹ (av. 5) Specific conductivity ranged between 75 and 140 μ Scm⁻¹ (av. 95) and total dissolved solids from 49 to 91 mg^l⁻¹ (av. 62). Calcium ion was moderate (11-23; av. 17 mg^l⁻¹). Magnesium occurred in the range 2-10; av. 6 mg^l⁻¹. Total hardness was in the range 48-96 mg^l⁻¹ (av. 67).

Phosphates and nitrates were poor, the former ranged from traces to 0.09 mg^l⁻¹ (av. 0.03) and the latter from 0.02 to 0.22 mg^l⁻¹ (av. 0.08). The loading of nutrients from the catchment appears to be poor. The concentration of silicates (SiO₂) was normal ranging from 6 to 10 mg^l⁻¹ (av. 8). Chlorides ranged from 4 to 49 mg^l⁻¹ (av. 18).

The water quality parameters such as total alkalinity, specific conductivity and hardness indicated medium range of productivity, while nutrient level showed poor productivity of Tawa reservoir.

Thermal and chemical stratification

Thermal stratification was observed only during summer (Mar-Apr). The epilimnion extended upto 6 m with isothermal water regime. The thermocline was noted between 7 and 8 m depth characterised by a steep fall in temperature ranging from 3.0 to 3.4°C (Fig. 3).

Weak biogenic chemical stratification occurred during March-May. The DO values declined from 7.6 ppm at surface to 3.8 ppm at bottom (10 m). pH and specific conductivity did not show any marked variation in the column. The strength of the oxycline is a good and dependable index of productivity of reservoir ecosystem. In Tawa reservoir the weak oxycline showed the low concentration of bottom deposits indicating low to medium productivity.

Primary production

Measurement of phytoplankton primary production is essential as it adds chemical energy and organic matter to reservoir ecosystem. Assessment of trophic status and fish production potential can be made through estimates of daily phytoplankton as well as seasonal carbon production. Apart from photosynthetic primary production which is merely a part of productivity substantial amount of energy in the form of allochthonous inputs is being added directly to the productivity at primary consumer level in reservoir ecosystem.

The gross (GPP) and net (NPP) primary production in Tawa reservoir varied from 450 to 2287 (av. 1390) and 74 to 628 mg C/m³/d (av. 480) respectively in 1995-96. The same values in 1996-97 were significantly low in the range 500 to 1250 (av. 900) and 125-500 mg C/m³/d (av. 370) respectively which was primarily due to the presence of significantly higher amounts of phytoplankton during 1995-96 (28.6%) as compared to 1996-97 (19%). The gross production was maximum in post-monsoon and monsoon periods rather than in summer months and minimum recorded in winter. Due to the dominance of zooplankton, community respiration (CR) surpassed NPP viz. 1092 and 636 mg C/m³/d in 1995-96 and 1996-97

respectively. The gross production to community respiration ratio (P:R) did not exhibit wide fluctuation (1.27 in 1995-96 and 1.42 in 1996-97) indicating a medium productivity of the reservoir (Table 4 and Fig. 4).

Biotic communities

Plankton

The standing crop (ml/m^3) of plankton in Tawa reservoir was 2.02 (1994-95), 2.00 (1995-96) and 1.67 (1996-97). Higher standing crops were obtained during years of higher inflows. Thus, plankton density (u/l) was significantly higher (2862) during 1994-95 (inflow 7847 million m^3) and low (1783) during 1996-97 (inflow 2359 million m^3). A plankton pulse was observed during post-monsoon months (Sep-Nov). The allochthonous inputs during monsoon followed by a stable water condition in post-monsoon months contributed for this plankton pulse. The summer pulse was observed during May-June. Plankton was poor in monsoons due to high turbidity, dilution and dislodging of the bottom caused by the monsoon flushing. No distinct winter pulse was observed during the course of this study.

Sector-wise, standing crop was rich in intermediate sector in all the years (2.5-3.2 ml/m^3), followed by lotic (1.4-2.2 ml/m^3) and lentic (1.5-2.0 ml/m^3) sectors. Denwa stretch (0.7-1.1 ml/m^3) has relatively low concentration. The intermediate sector being comparatively less disturbed zone had higher magnitude of plankton.

Zooplankton (71-81%) was predominant in all the years. Among zooplankton, Copepods (36-44%) were the most important followed by cladocerans (14-16%), rotifers (11-15%) and protozoans (2-10%). The abundance of phytoplankton was low throughout the period and was represented by Myxophyceae (5-12%), Chlorophyceae (8-12%) and Bacillariophyceae (4-11%) (Fig. 5).

Planktonic forms encountered are presented in the Table 5. The plankton diversity of Tawa reservoir is quite rich (when compared to other Indian reservoirs). In phytoplankton, Myxophyceae was represented by 11 species, Chlorophyceae by 18 species, Bacillariophyceae by 15 species, Dinophyceae by single species and Desmidiaceae by 3 species. The diversity of zooplankton is also impressive. Protozoa was represented by 4 forms, Rotifera by 23 species, Cladocera by 18 species, Copepoda by 6 species and Ostracoda by a single species.

Macro-benthos

Macro-benthic population of the reservoir ranged from 368 to 1727 nos/m^2 (av. 1000 nos/m^2) and the biomass from 144 to 1320 g/m^2 (av. 415 g/m^2). Macro-benthos exhibited sectoral variation with maximum density in intermediate sector (968-2009 nos/m^2 ; 128-859 g/m^2) as compared to lentic, lotic and Denwa sectors. An inverse relationship was observed between reservoir water level and macro-benthos. The minimum concentration was recorded in December (368 nos/m^2 ; 144 g/m^2) when the reservoir water level was high (355 m) and peak values (1727 nos/m^2 ; 1320 g/m^2) in June coinciding with the lowest water level (342 m) of the reservoir.

**Table 4. Carbon production and energy transformation
in Tawa reservoir**

Feature	1995-96	1996-97
GPP (mg C/m ³ /d)	1390	900
NPP (mg C/m ³ /d)	480	370
Comm. Resp. (mg C/m ³ /d)	1092	636
Net : Gross	0.35	0.41
P : R	1.27	1.42
Energy (KCal/ha/y) x 10 ⁶	50.74	32.85

Table 3. Physico-chemical features of water of Tawa reservoir (1995-97)

Parameter	Range	Mean
Water temperature (°C)	22.0-33.0	-
Transparency (cm)	17-228	112
pH	7.1-9.2	8.3
Dissolved Oxygen (mg ^l ⁻¹)	5.8-8.2	7.1
Sp. conductivity (μScm ⁻¹)	75-140	95
TDS (mg ^l ⁻¹)	49-91	62
Free CO ₂ (mg ^l ⁻¹)	Nil-8	3.7
Carbonates (mg ^l ⁻¹)	Nil-18.5	5.1
Bicarbonates (mg ^l ⁻¹)	46-85	66.5
Total alkalinity (mg ^l ⁻¹)	46-97	71.6
Phosphates (mg ^l ⁻¹)	Tr.-0.09	0.03
Nitrates (mg ^l ⁻¹)	0.02-0.22	0.09
Silicates (mg ^l ⁻¹)	6-10	8.2
Ca ⁺⁺ (mg ^l ⁻¹)	11-23	17.0
Mg ⁺⁺ (mg ^l ⁻¹)	2-10	6.0
Hardness (mg ^l ⁻¹)	48-96	67.0
Chloride (mg ^l ⁻¹)	4-49	18.5
DOM (mg ^l ⁻¹)	1.25-4.42	2.84
Fe (mg ^l ⁻¹)	0.03-2.64	0.87
Mn (mg ^l ⁻¹)	0.05-0.12	0.08
Zn (mg ^l ⁻¹)	0.06-0.096	0.078
Na (mg ^l ⁻¹)	6.1-6.6	6.3
K (mg ^l ⁻¹)	2.37-2.65	2.51

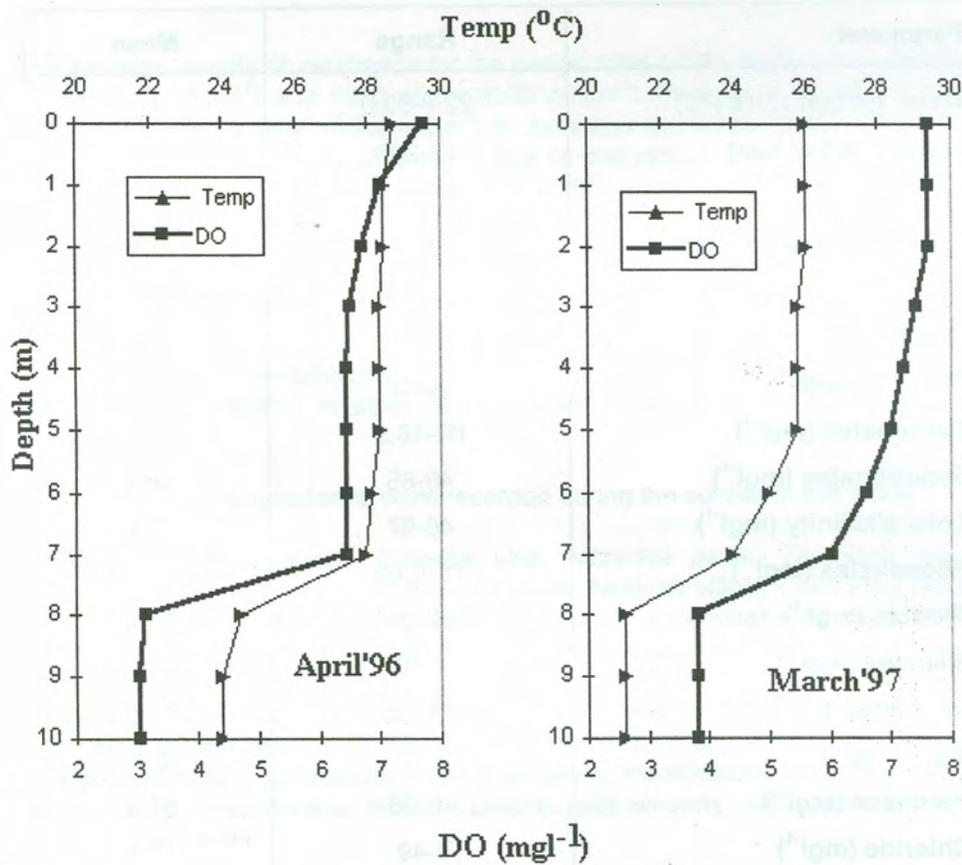


Fig. 3. Stratification in Tawa reservoir

Table 5. Plankton diversity in Tawa reservoir

Phytoplankton		Zooplankton	
<p>Myxophyceae <i>Microcystis aeruginosa</i> <i>Oscillatoria sp.</i> <i>Johannesbaptistia pellucida</i> <i>Anacystis cyanea</i> <i>Anacystis sp.</i></p> <p><i>Anabaena sp.</i> <i>Aphanocapsa sp.</i> <i>Gomphosphaeria sp.</i> <i>Chroococcus sp.</i></p> <p><i>Amphithrix janthina</i> <i>Coelosphaerium sp.</i></p> <p>Bacillariophyceae <i>Fragilaria sp.</i> <i>Gyrosigma kutzingii</i> <i>Navicula sp.</i> <i>Surirella sp.</i> <i>Meridion sp.</i> <i>Melosira sp.</i> <i>Eunotia sp.</i> <i>Synedra ulna</i> <i>Synedra sp.</i> <i>Bacillaria paradoxa</i> <i>Opephora martyi</i> <i>Cymbella sp.</i> <i>Nitzschia sp.</i> <i>Cocconeis placentula</i> <i>Cocconeis sp.</i></p>	<p>Chlorophyceae <i>Pediastrum simplex</i> <i>Pediastrum duplex</i> <i>Pediastrum sp.</i></p> <p><i>Microspora sp.</i> <i>Gonatozygon sp.</i></p> <p><i>Hormidium subtile</i> <i>Hormidium sp.</i> <i>Actinastrum sp.</i> <i>Basicladia sp.</i></p> <p><i>Ankistrodesmus sp.</i> <i>Pandorina sp.</i> <i>Spirogyra sp.</i> <i>Tetraspora sp.</i> <i>Botryococcus sp.</i> <i>Coelastrum sp.</i> <i>Protococcus sp.</i> <i>Eudorina sp.</i> <i>Treubaria sp.</i></p> <p>Dianophyceae <i>Ceratium hirudinella</i></p> <p>Desmidiaceae <i>Campylodiscus sp.</i> <i>Closterium sp.</i> <i>Genicularia sp.</i></p>	<p>Protozoa <i>Diffugia sp.</i> <i>Centropyxis sp.</i> <i>Arcella sp.</i></p> <p><i>Vampyrella sp.</i></p> <p>Rotifera <i>Keratella valga</i> <i>Keratella sp.</i> <i>Brachionus quadridentata</i> <i>Brachionus bidentata</i> <i>Brachionus angularis</i> <i>Brachionus sp.</i> <i>Filinia brachiata</i> <i>Filinia longiseta</i> <i>Filinia sp.</i> <i>Cephalodella auriculata</i> <i>Conochilus hippocrepis</i> <i>Conochilus sp.</i> <i>Testudinella sp.</i> <i>Polyarthra sp.</i> <i>Trichocerca sp.</i> <i>Asplanchna sp.</i> <i>Chromogaster sp.</i> <i>Synchaeta sp.</i> <i>Anuraeopsis fissa</i> <i>Anuraeopsis sp.</i> <i>Hexarthra sp.</i> <i>Mytilina sp.</i> <i>Ascomorpha sp.</i></p>	<p>Ostracoda <i>Cypris sp.</i></p> <p>Cladocera <i>Daphnia sp.</i> <i>Ceriodaphnia cornuta</i> <i>Ceriodaphnia sp.</i> <i>Ctenodaphnia sp.</i> <i>Chydorus ovalis</i> <i>Chydorus sphaericus</i> <i>Chydorus sp.</i> <i>Bosmina sp.</i> <i>Diaphanosoma sp.</i> <i>Acroperus sp.</i> <i>Alonella sp.</i> <i>Moina sp.</i> <i>Alona sp.</i> <i>Sida sp.</i> <i>Bosminopsis deitersi</i> <i>Bosminopsis sp.</i> <i>Macrothrix sp.</i> <i>Simocephalus sp.</i></p> <p>Copepoda <i>Diaptomus gracilis</i> <i>Diaptomus sp.</i> <i>Cyclops sp.</i> <i>Mesocyclops sp.</i> <i>Canthocampus sp.</i> <i>Metis sp</i> <i>Nauplii</i></p>
Fungi			
<i>Actinospora megalospora, Nowakowskiella elegans</i>			

Bathymetric distribution revealed greater density upto 8 m (911-1091 nos/m²) declining thereafter (410-863 nos/m²) at 10-20 m. Numerically, dipterans (44.5%) were the most important group followed by gastropods (39.7%), bivalves (10.6%), caddis worms (2.9%) and oligochaetes (2.3%). Dragon fly nymphs occurred occasionally. However, molluscs accounted for the bulk of benthic biomass (Fig. 6).

The benthic forms encountered in Tawa are : *Melanoides*, *Viviparus*, *Lymnaea*, *Gyraulus* (Gastropoda), *Corbicula*, *Parreysia*, *Lamellidens*, *Ligumia* (Bivalvia), *Chironomus*, *Chaoborus*, *Culicoides* (Dipteran larvae), *Hydropsyche* (Trichoptera), *Nais*, *Chaetogaster*, *Lumbriculus* (Oligochaeta) and *Aeshna* (Odonata).

Periphyton

The average density of periphyton for the period 1995-97 fluctuated in a narrow range between 1288 (0.17 ml/cm²) and 1318 u/cm² (0.20 ml/cm²). Periphyton showed two distinct peaks annually, a summer peak (4655 u/cm²) in June and the winter peak (3704 u/cm²) in December. It was poor during July (228 u/m²) due to disturbed water condition. Periphyton exhibited sectoral variations. The lentic sector (1382-2030 u/cm²) was richer as compared to intermediate (51-503 u/cm²), lotic (69-364 u/cm²) and Denwa sectors (40-345 u/cm²). The lentic sector offers more natural substrata for the deposition of periphyton in the reservoir.

Diatoms (68.1-83.8%) were dominant in periphyton followed by green algae (14.1-17.5%), blue-green algae (1.9-12.2%) and desmids (0.2-2.2%). Myxophyceae (69.6%) was important in August, Chlorophyceae in May (74.1%) and February (85.3%) and Bacillariophyceae (62.1-90.9%) in other months. Desmidiaceae (0.5-9.4%) was poor and occurred scarcely (Fig. 7).

The following periphytic forms were recorded during the course of this study

Bacillariophyceae : *Navicula* sp., *Synedra ulna*, *Nitzschia palea*, *Tabellaria jenestrata*, *Amphora ovalis*, *Fragilaria cepucina*, *Rhopalodia gibba*, *Neidium affinis*, *Cocconeis placentula*, *Meridion circulare*, *Cymbella cistula*, *Frustulia rhombiodes*, *Asterionella japonica*, *Diatomella* sp., *Surirella robusta*, *Gyrosigma* sp., and *Gomphonema aquatum*.

Chlorophyceae : *Pediastrum simplex*, *Spirogyra* sp., *Ulothrix* sp., *Basicladia chelonum*, *Gonatozygon* sp., *Ankistrodesmus* sp., *Euglena* sp., *Hormidium* sp., *Phacus* sp., *Schizomeris leibleinii*, *Oedogonium* sp., *Characium ornithocephalum*, *Pachycladon umbrinus*, *Pandorina morum*, *Eudorina* sp., *Pascheriella tetras*, *Sphaerocystis elegans*, *Microspora amoena* and *Scenedesmus quadricauda*

Myxophyceae : *Microcystis* spp., *Oscillatoria chlorina*, *Amphithrix janthina*, *Microcrosis geminata*, *Stichosiphon sasibaricus*, *Capsosira brebissonii*, *Raphidiopsis curvata*, *Aphanizomenon holsaticum*, *Nodularia* sp., *Merismopedia* sp., *Phormidium* sp. and *Anabaena spiroides*

Desmidiaceae : *Cosmarium monomazum*, *Cicsterium acerosum* and *Staurastrum chaetoceros*

Macrophytes

Stray occurrence of *Hydrilla* and *Vallisneria* was noted in winter months in shallow areas which disappeared with the decline in water levels.

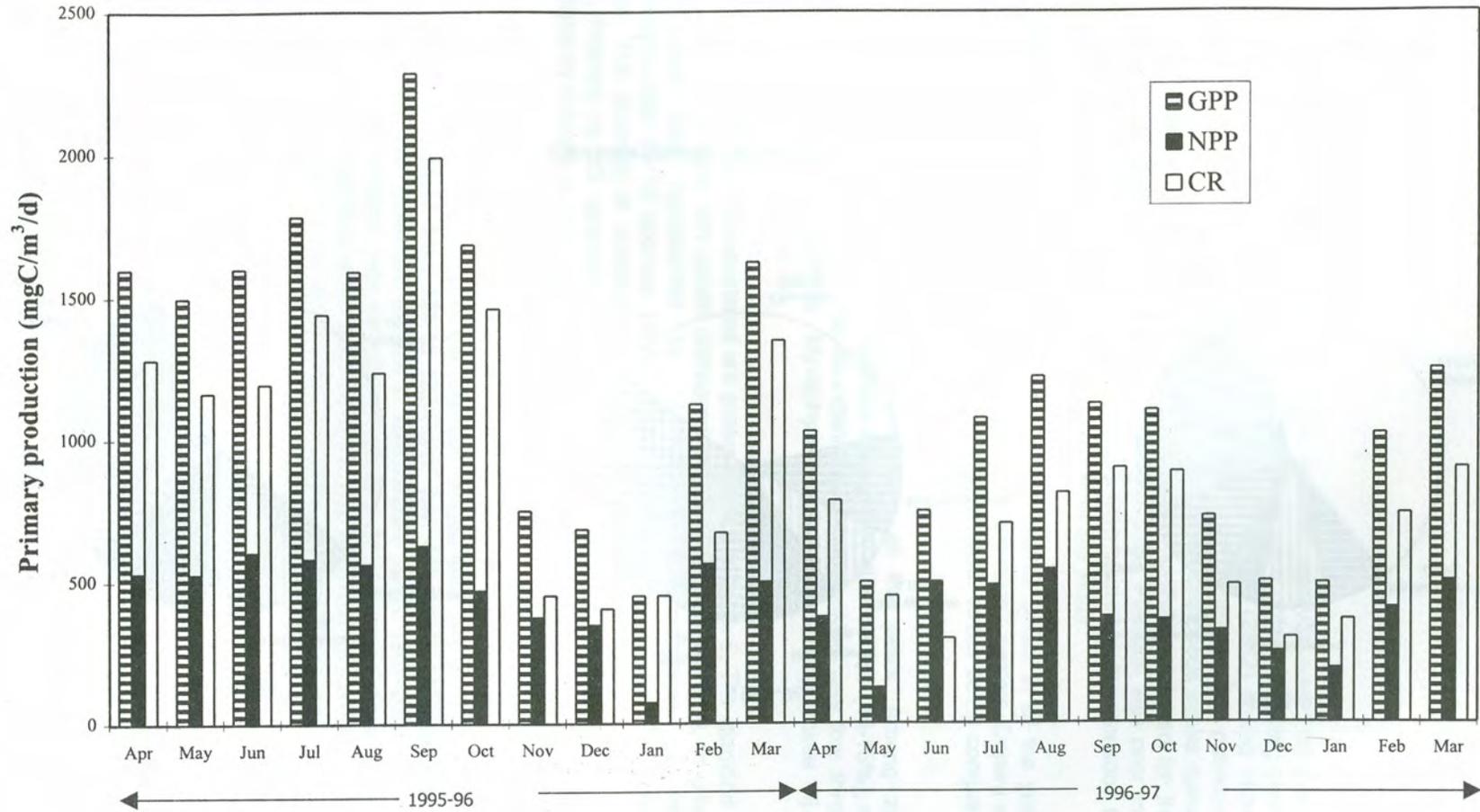


Fig. 4. Primary production and community respiration in Tawa reservoir

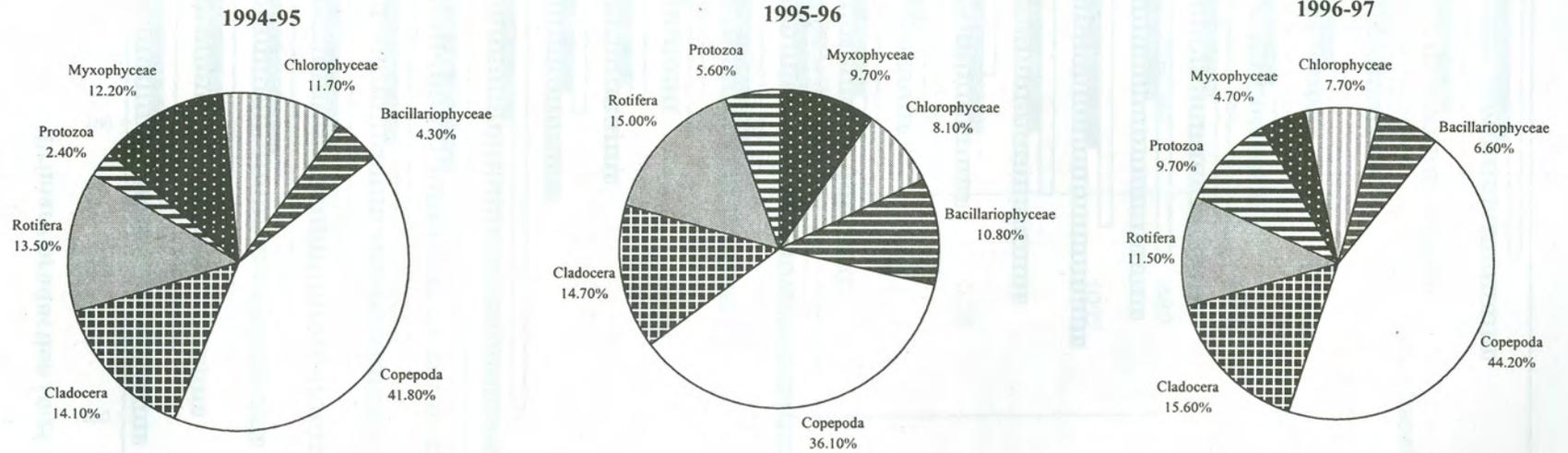


Fig. 5. Plankton (quality composition) of Tawa reservoir

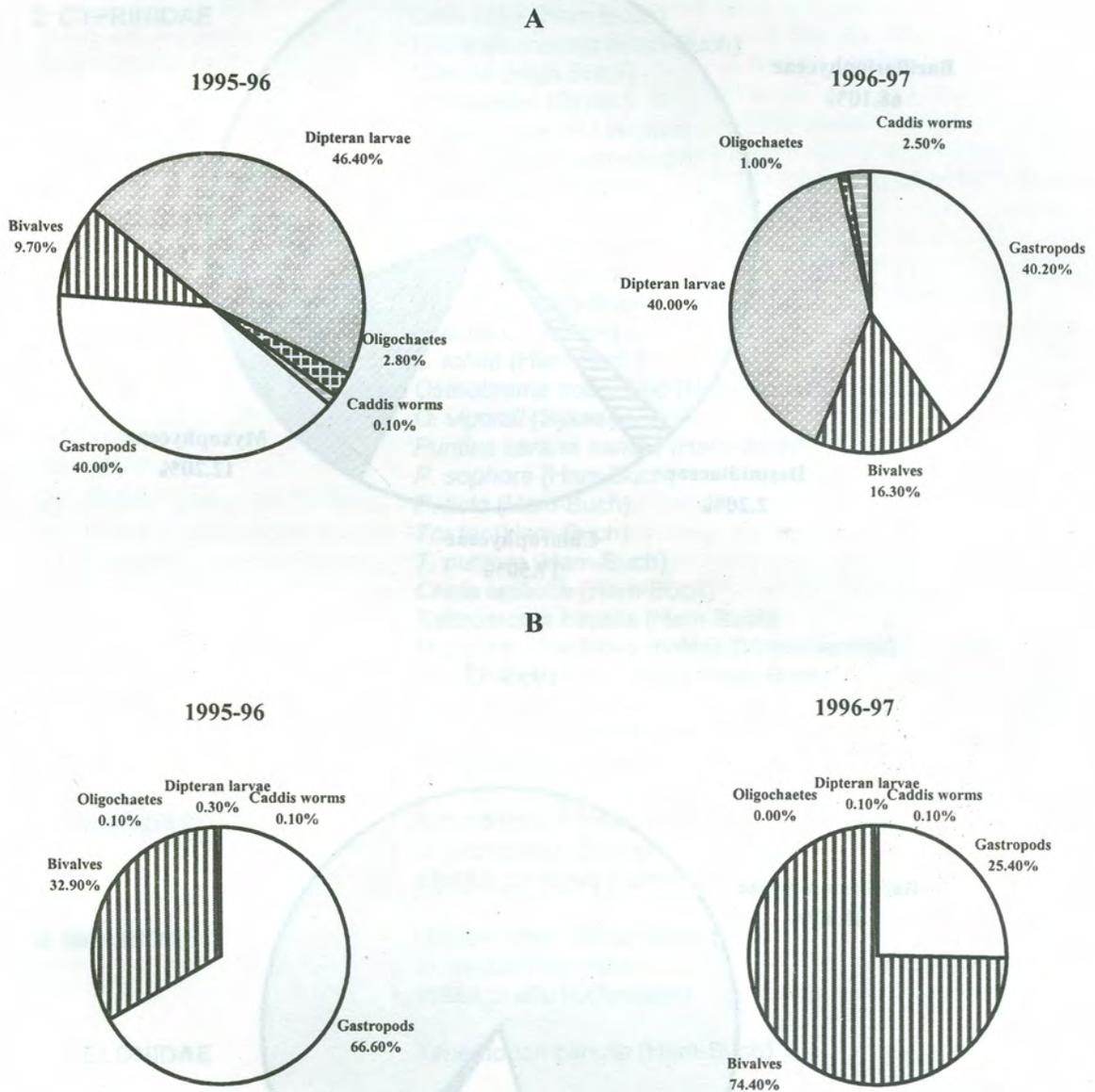
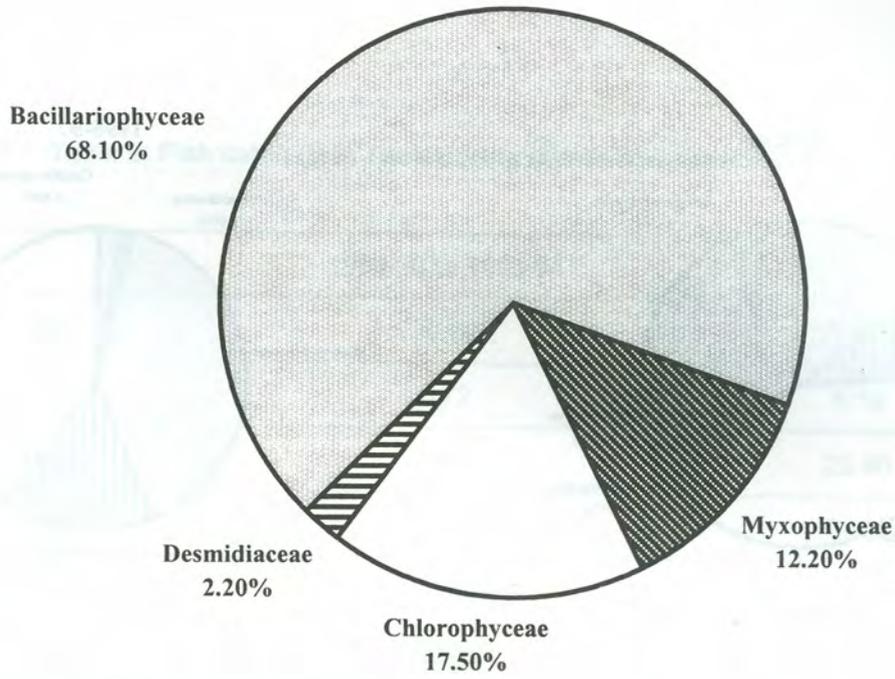


Fig. 6. Macro-benthos (quality composition) of Tawa reservoir, by Number (A) and by Weight (B)

1995-96



1996-97

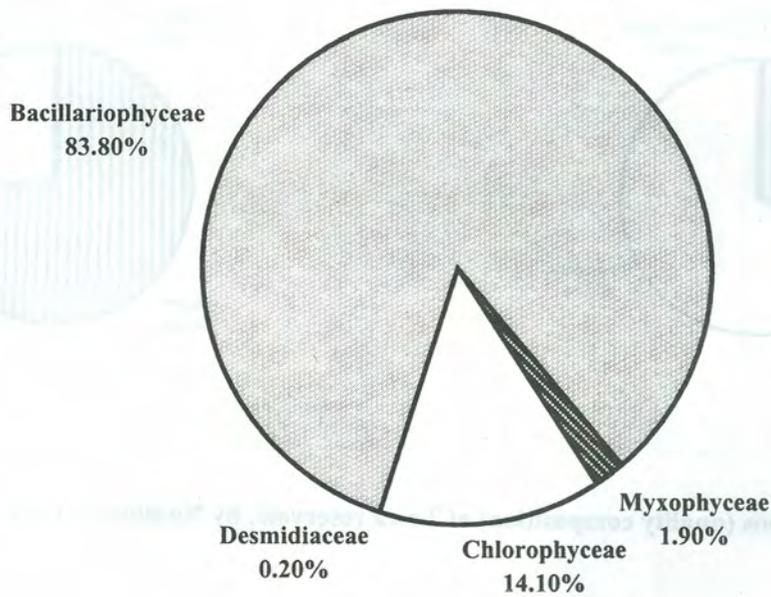


Fig. 7. Periphyton (quality composition) of Tawa reservoir

Fish fauna

Forty three species belonging to ten families and twenty six genera recorded from Tawa reservoir are listed below.

1. **NOTOPTERIDAE** : *Notopterus notopterus* (Pallas)
2. **CYPRINIDAE** : *Catla catla* (Ham-Buch)
Cirrhinus mrigala (Ham-Buch)
C. reba (Ham-Buch)
C. fulungee (Sykes)
Cyprinus carpio Linnaeus
Labeo angra (Ham-Buch)
L. bata (Ham-Buch)
L. boggut (Sykes)
L. calbasu (Ham-Buch)
L. fimbriatus (Bloch)
L. gonius (Ham-Buch)
L. kontius (Jerdon)
L. rohita (Ham-Buch)
Osteobrama cotio cotio (Ham-Buch)
O. vigorsii (Sykes)
Puntius sarana sarana (Ham-Buch)
P. sophore (Ham-Buch)
P. ticto (Ham-Buch)
Tor tor (Ham-Buch)
T. putitora (Ham-Buch)
Chela laubuca (Ham-Buch)
Salmostoma bacaila (Ham-Buch)
Hypophthalmichthys molitrix (Valenciennes)
Amblypharyngodon mola (Ham-Buch)
Barilius barila (Ham-Buch)
B. bendelisis (Ham-Buch)
Parluciosoma daniconius (Ham-Buch)
3. **BAGRIDAE** : *Aorichthys aor* (Ham-Buch)
A. seenghala (Sykes)
Mystus cavasius (Ham-Buch)
4. **SILURIDAE** : *Ompok bimaculatus* (Bloch)
O. pabda (Ham-Buch)
Wallago attu (Schneider)
5. **BELONIDAE** : *Xenentodon cancila* (Ham-Buch)
6. **AMBASSIDAE** : *Chanda nama* (Ham-Buch)
Pseudambassis ranga (Ham-Buch)
7. **SCHILBEIDAE** : *Clupisoma garua* (Ham-Buch)
Eutropiichthys vacha (Ham-Buch)

8. MUGILIDAE : *Rhinomugil corsula* (Ham-Buch)
9. CHANNIDAE : *Channa marulius* (Ham-Buch)
C. striatus (Bloch)
10. MASTACEMBELIDAE : *Mastacembelus armatus* (Lacepede)

Three specimen of silver carp (*H. molitrix* 620-630 mm, 2.6-2.75 kg) were recorded in Tawa reservoir for the first time at Banglapura landing centre on 11.06.97, caught in the shore seine. The specimens appear to be of 1+ age group. It is gathered that silver carp has never been stocked either in Tawa or in the upstream Sarni reservoir. The fish appears to be an accidental entrant along with major carp seed. Its occurrence in Tawa reservoir is rather disturbing in view of its known competition with catla which forms the mainstay of fishery of Tawa. If silver carp establishes in the reservoir, it is bound to have an adverse effect on catla fishery.

Fishery

Craft and gear

Small non-mechanised flat bottomed canoes (4-5 m) made of G.I. sheet (20 gauge) and marine plywood are used for commercial fishing. Tawa Matsya Sangh, Kesla, presently engaged in the fishery management has two outboard 5 HP motor boats.

Simple gill nets locally known as 'Phasla' are mainly used in the fishing. Polyamide (PA) multifilament webbings are generally used in gill nets of varying mesh sizes (50-100 mm bar). Gill nets possess nylon head rope and floats but no foot rope and sinkers. The expanded polystyrene, commonly known as thermocole, is used as floats.

Shore seine popularly known as 'Mahajal' is used during summer months at low water levels. The Mahajal consists of a central bag of 50 m length and two wings of three segments each. These segments are also 50 m each in length. The central bag is made of PA 210/613. It has a depth of 7.5 m and a mesh size of 40 mm. The three segments of the wing from the central bag towards the end decrease in depth 6, 4 and 3 m but the mesh sizes increase like 80, 100 and 120 mm respectively. Polyethylene twine of 20 mm diameter is used as head rope and manila rope (20 mm dia) as foot rope. Thermocole pieces are used as floats attached to the head rope at an interval of 2 m and stone sinkers are attached to the foot rope at an interval of 5 m.

Besides nets, the traditional long lines are also operated. The gear has a main line of PA 210/6/3 and branch lines of PA 210/5/3 and 300 to 400 hooks are used in one unit. Hook No. 8, 9 and 11 are used in long line fishing.

Landing centres

There are three fish landing centres - Tawanagar, Banglapura and Kamthi (Tekapar). The catches of Tawanagar and Banglapura centres are taken to the main assembling centre at Kesla, whereas the catch of Kamthi centre is disposed off locally. The fish, packed in ice, is sent to different destinations including Howrah. The cost of packing 1 kg of fish ranges from 2 to 4 rupees depending on the season.

Fishing effort

A fishing unit includes one boat, three fishermen and 25 kg of nets. The fishing units employed in the commercial fishing varied from 50 (1994-95) to 104 (1998-99) per day. During 1994-95 fishing was conducted for 211 days. But in the following two years there was a drastic reduction in effort due to administrative problems. Fishing could be conducted only for 76 days during 1995-96 and 85 days during 1996-97. However, normal fishing resumed in 1997-98 with 267 fishing days and 257 days during 1998-99 (Table 6).

Fish catch and catch composition

The total catch from Tawa reservoir during the first five years of its formation (1974-75 to 1978-79) ranged from 0.019 to 0.325 t. The poor catches may be due to low effort and lack of sufficient infrastructure for management in the initial stages. Subsequently, during 1979-80 to 1998-99, the catch varied from 16.5 t (1.4 kg/ha) in 1984-85 to 344.4 t (28.1 kg/ha) in 1998-99. The production which was low (4 kg/ha) till 1986-87, improved considerably in successive years and touched the peak (28 kg/ha) in 1998-99. The enhanced rate of stocking from 1987-88 onwards coupled with increase in fishing effort contributed to the increase in production.

The details of fish catch and its composition during 1989-90 to 1998-99 (10 years) are presented in Table 7. The catch during the five year period prior to the present study is also given for comparison (Table 8). *C. catla* (av. 71.1%), formed the main fishery of Tawa reservoir. Catla weighing upto 5 kg was the dominant group (87%) and above 5 kg (13%) was rare in the catch (Table 9, Fig 9). The catches of catla improved over the years reaching the maximum of 232.3 t in 1998-99. However, its contribution in the total catch declined from 85 to 67%.

C. mrigala contributed 2.3 t (2.7%) in 1993-94 but significantly improved to 44 t (12.8%) in 1998-99. The contribution of *L. rohita* was poor (0.2 to 8.8 t) throughout the period. A rare occurrence of catla-rohu hybrid was also observed in Tawa reservoir (Fig. 8).

The indigenous fishes, represented by large catfishes, native carps and others contributed 6.2 t in 1993-94 and 59.3 t in 1998-99. These included *W. attu*, *A. aor*, *A. seenghala*, *L. calbasu*, *L. fimbriatus*, *L. gonius*, *P. sarana* and *N. notopterus*. The contribution of mahseer, *T. tor* (0.6%) was not significant. Though the fishery of Mahseer was negligible in Tawa, it was available in wider size range (260-700 mm; 0.2-5.0 kg) indicating its breeding and recruitment in the reservoir.

Miscellaneous fishes contributed 15 t to the total catch during 1994-95, but in recent years due to mesh regulation they do not occur in the catches. The important species are *O. cotio*, *C. nama*, *P. ranga*, *Chela spp.*, *Puntius spp*, *A. mola*, *B. barila*, *B. bendelisis*, *p. daniconius*, *X. cancila* etc.

Table 6. Fishing effort, and CPUE in relation to water level in Tawa reservoir

Year	Fishing units/day	Fishing days	Fishing effort	Increase/decrease in effort (%)	Catch (t)	Increase/decrease in catch (%)	CPUE	Average water level (m) during fishing period
1994-95	50	221	11050	-	176.182	-	15.9	349
1995-96	53	76	4028	- 63	93.538	- 46	23.2	345
1996-97	76	85	6460	- 41	93.230	- 47	14.4	350
1997-98	64	267	17088	54	245.853	39	14.4	351
1998-99	104	257	26728	142	344.375	95	12.9	352

One unit = 1 boat, 3 fishermen & 25 kg nets

Table 7. Fish catch (t) and its composition in Tawa reservoir

Fish	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
<i>C. catla</i>	135.8 (82.1)	104.6 (80.0)	112.9 (77.3)	72.7 (82.0)	72.2 (85.6)	115.8 (65.7)	57.7 (61.7)	47.4 (50.9)	163.5 (66.5)	232.3 (67.4)
<i>L. rohita</i>	1.1 (0.7)	0.5 (0.4)	1.5 (1.0)	0.3 (0.3)	0.2 (0.2)	3.8 (2.1)	2.7 (2.9)	4.3 (4.6)	6.2 (2.5)	8.8 (2.6)
<i>C. mrigala</i>	7.6 (4.6)	3.9 (3.0)	10.3 (7.1)	3.0 (3.4)	2.3 (2.7)	9.8 (5.6)	6.2 (6.6)	21.7 (23.3)	30.3 (12.4)	44.0 (12.8)
Total major carps	144.5 (87.4)	109.0 (83.4)	124.7 (85.4)	76.0 (85.7)	74.7 (88.5)	129.4 (73.4)	66.6 (71.2)	73.4 (78.8)	200.0 (81.4)	285.1 (82.8)
Indigenous species	19.2 (11.6)	12.6 (9.6)	18.0 (12.3)	6.3 (7.1)	6.2 (7.3)	31.4 (17.8)	23.1 (24.7)	19.8 (21.2)	45.8 (18.6)	59.3 (17.2)
Miscellaneous	1.6 (1.0)	9.1 (7.0)	3.3 (2.3)	6.4 (7.2)	3.5 (4.2)	15.4 (8.8)	3.8 (4.1)	-	-	-
Total catch	165.3	130.7	146.0	88.7	84.4	176.2	93.5	93.2	245.8	344.4
Yield (kg /ha)	13.5	10.7	11.9	7.3	6.9	14.4	7.6	7.6	20.0	28.1

(Figures in parenthesis are percentages)

Table 8. Fish catch (t) in Tawa during different quinquenniums

	1989-90 to 1993-94	1994-95 to 1998-99
<i>C. catla</i>	99.64	123.34
<i>L. rohita</i>	0.72	5.16
<i>C. mrigala</i>	5.42	22.40
Native fish	12.46	35.88
Miscellaneous	4.78	3.84
Total catch	123.02	190.62
Catch/ha (kg)	10.05	15.57

Table 9. Contribution of different size groups of *C. catla* to the catch in Tawa reservoir

Year	> 5 kg		3- 5 kg		< 3 kg		Total	
	No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)
1989-90	3258	18.4	13133	45.3	33096	72.1	49487	135.8
1990-91	3140	17.1	14081	46.7	18609	40.2	35830	104.0
1991-92	2594	14.1	17309	57.8	18185	40.4	38088	112.3
1992-93	1883	10.1	10973	36.7	12067	25.9	24923	72.7
1993-94	1482	8.1	10903	37.1	11653	26.1	24038	71.3
1994-95	2429	14.0	17426	60.5	17361	41.1	37216	115.6
1995-96	1090	6.1	7476	29.0	8877	22.6	17443	57.7
1996-97	438	2.4	3718	13.2	14203	31.8	18359	47.4
1997-98	1283	6.8	21390	79.4	32132	77.3	54805	163.5
1998-99	8749	45.2	27615	96.9	37227	90.2	73591	232.3

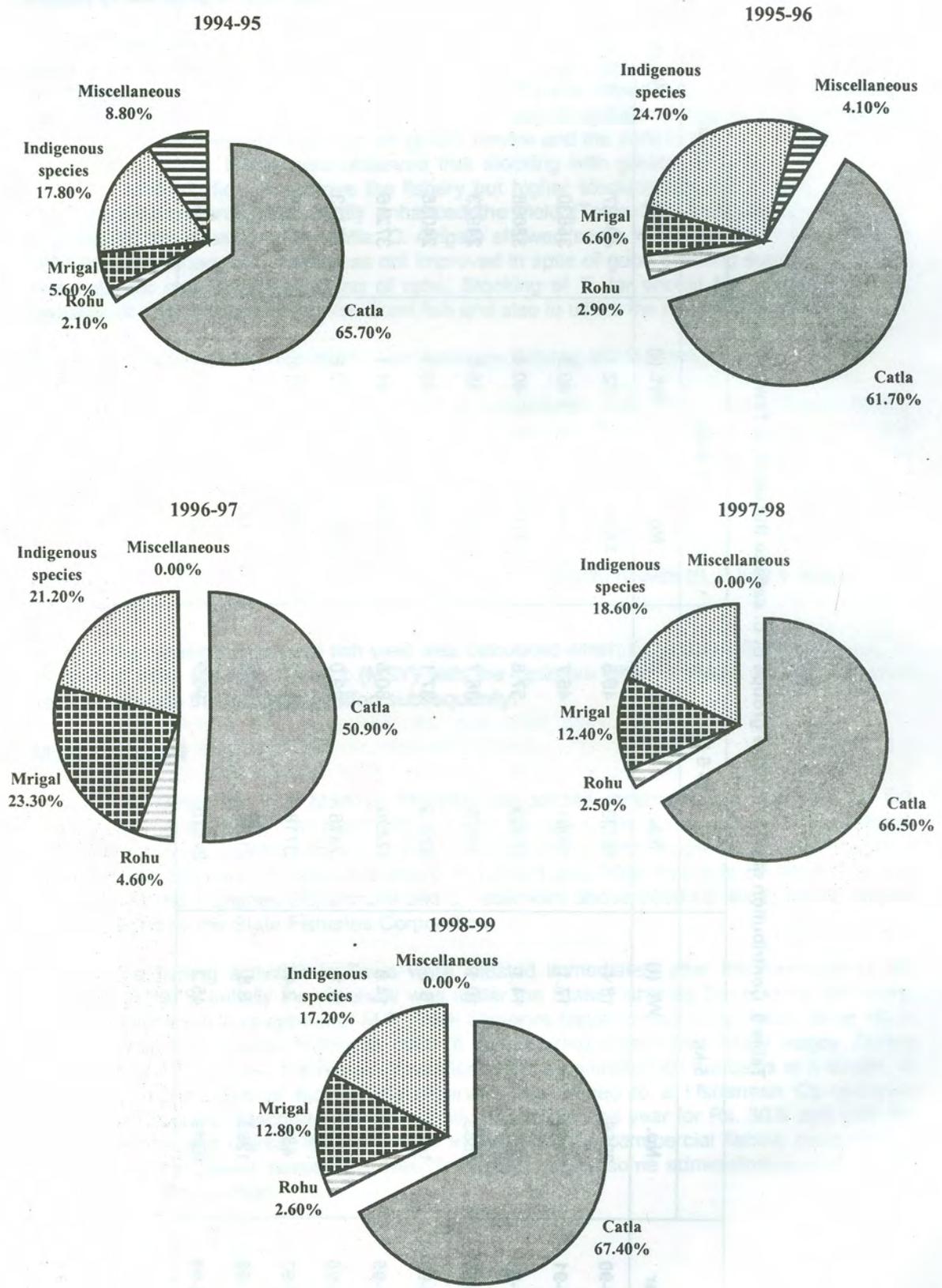


Fig. 8. Fish catch composition of Tawa reservoir

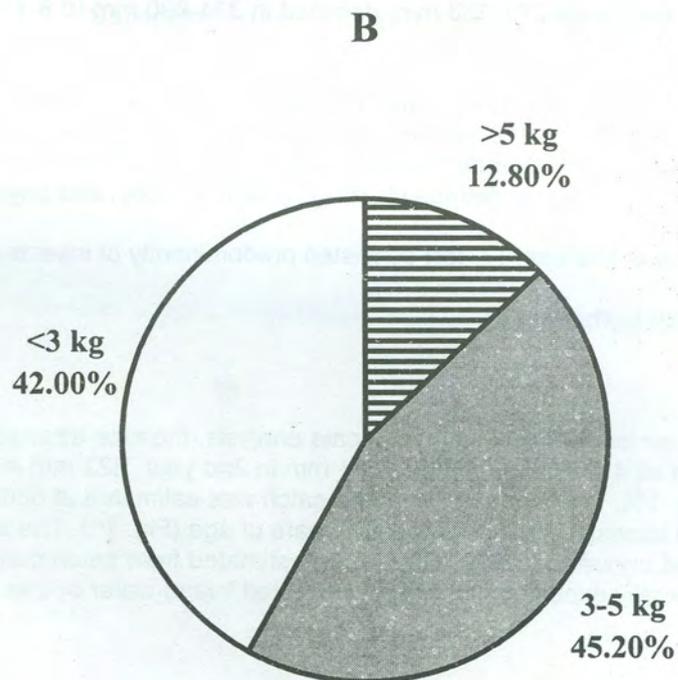
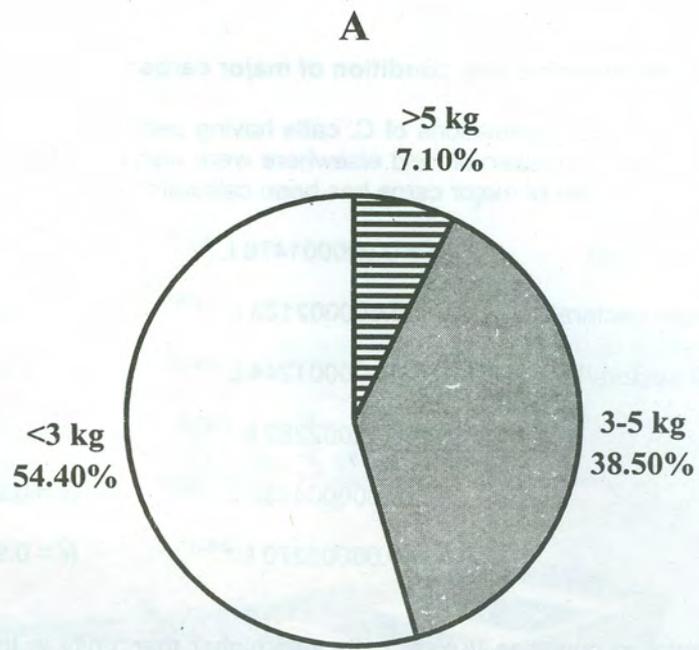


Fig. 9. Catch composition of three categories of *C. catla* in Tawa reservoir by Number (A) and by Weight (B) (1989-90 to 1998-99)

Biology of fish

Length-weight relationship and condition of major carps

Three ecological populations of *C. catla* having pectoral fin of different lengths which were observed in Rihand reservoir and elsewhere were also recorded in Tawa reservoir. The length-weight relationship of major carps has been calculated as :

<i>C. catla</i> (long pectoral)	: W = 0.000001476 L ^{3.3561}	(r = 0.9958)
<i>C. catla</i> (medium pectoral)	: W = 0.000002123 L ^{3.3052}	(r = 0.9998)
<i>C. catla</i> (short pectoral)	: W = 0.000001244 L ^{3.4068}	(r = 0.9918)
<i>L. rohita</i>	: W = 0.00002282 L ^{2.8828}	(r = 0.9937)
<i>C. mrigala</i>	: W = 0.000004452 L ^{3.1350}	(r = 0.9992)
<i>T. tor</i>	: W = 0.00003270 L ^{2.8217}	(r = 0.9923)

The relative condition (Kn) of catla was higher than unity in the size range 454-657 mm (1.0-1.1) with little fluctuations. The values declined in the size range 658-810 mm (0.9-1.0). In *L. rohita*, Kn values increased from the size range 352-402 mm (0.9) to 556-606 mm (1.1) and then declined in 607-759 mm (0.8). In *C. mrigala*, the condition was found to be good throughout the size range 250-810 mm (1.0-1.1). The Kn values in *T. tor* which were higher (1.0-1.3) in the size range 271-333 mm, declined in 334-690 mm (0.8-1.0) and again improved in 691-795 mm (1.0-1.1).

The Gastro-somatic index (GSI) indicated that the gut contents of *C. catla* (490-650 mm) were poor throughout the year except in April (GSI = 1.2-1.4). GSI was extremely poor (0.4-0.5) in June-July, the breeding period. The food consisted predominantly of zooplankton (60-85%) followed by organic detritus (5-25%), insects (5-20%) and phytoplankton (5%).

The food of Mahseer (*T. tor*) consisted predominantly of insects and molluscs.

Age / size group in the catch

Catla catla

Based on length frequency and scale analysis, the size attained at different ages has been estimated as 412 mm in 1st year, 541 mm in 2nd year, 623 mm in 3rd year and 692 mm in 4th year (Fig. 10). The mean length in the catch was estimated at 580 mm (3 kg). The fish is being exploited intensively in two and three years of age (Fig. 11). The instantaneous mortality rate (1.187) and annual mortality rate (0.688) estimated from catch curve are high. Such high values are generally expected in intensely exploited inland water bodies.



Sampling work of Tawa reservoir



Operation of shooting net in Tawa reservoir



Fishermen with drag net



Collection of minnows



Catla catch at Kamthi



Fish catch at Kamthi



Fish landing centre, Banglapura



Catla catch of Tawa reservoir



Weighing of fish catch at landing centre



Catla populations with long and medium pectoral fin

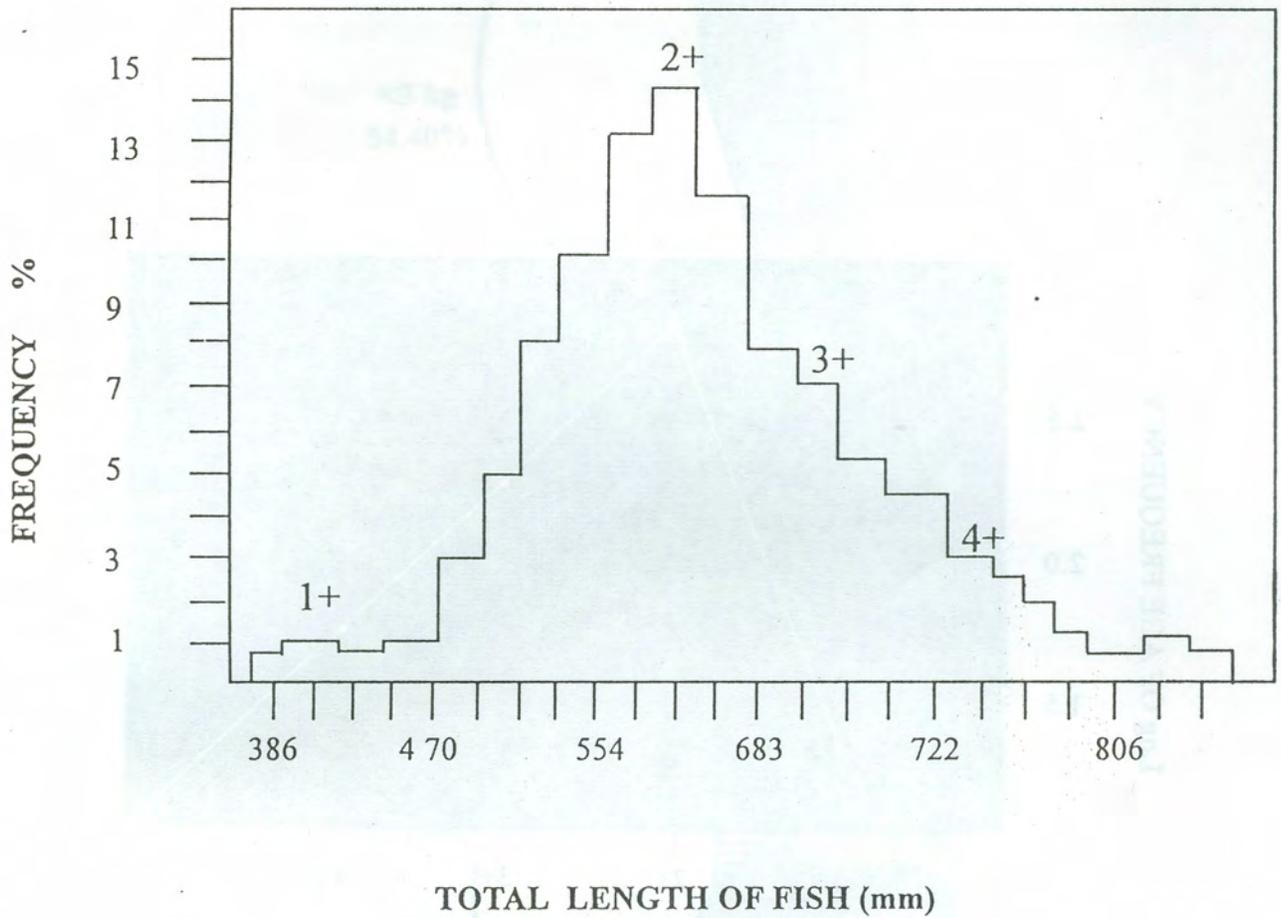


Fig. 10. Length-frequency of *C. catla* from Tawa reservoir

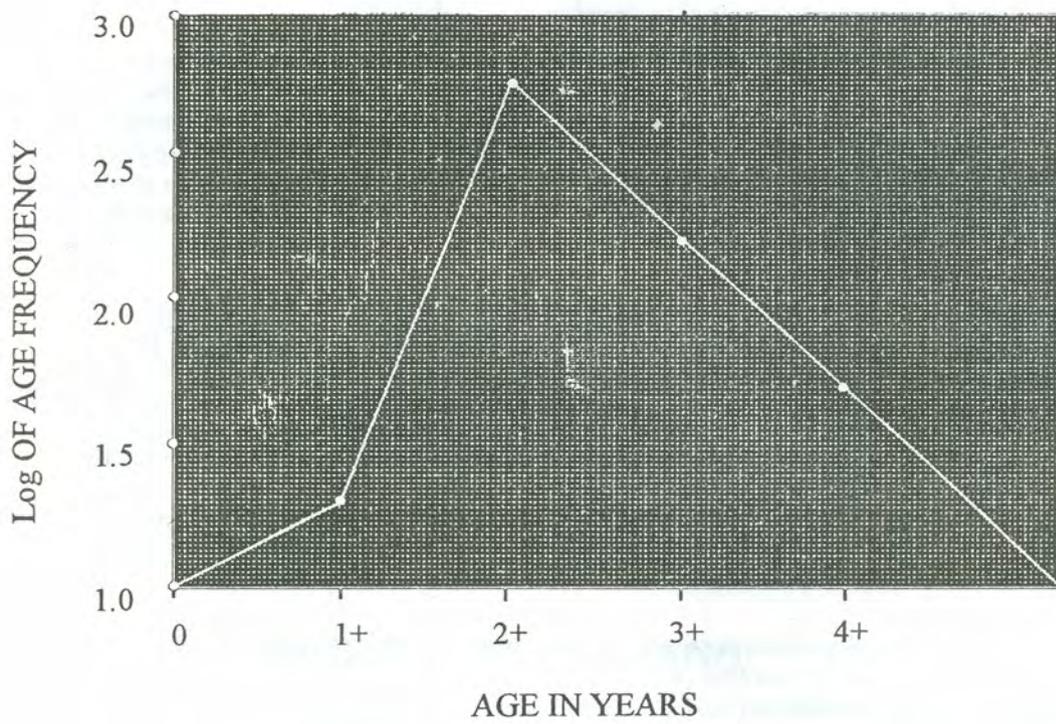


Fig. 11. Catch curve of *C. catla* from Tawa reservoir

Cirrhinus mrigala

Based on scale analysis, the size attained at different ages has been estimated as 367 mm in 2nd year, 510 mm in 3rd year, 607 mm in 4th year and 693 mm in 5th year. The growth of *C. mrigala* appears to be better than in Ravishankar Sagar (365 to 548 mm in 2nd to 4th years), another reservoir in M.P. which may be due to its low stocking.

Labeo rohita

On the basis of scale analysis, the size attained at different ages was estimated as 359 mm in 2nd year, 466 mm in 3rd year and 540 mm in 4th year. Growth of *L. rohita* is poor in Tawa. It is slower than that in Ravishankar Sagar reservoir (407-563 mm in 2-4 years). It could not establish in Tawa reservoir despite the good stocking support.

Tor tor

The size at different ages through scale analysis was estimated as 365 mm in 2nd year, 451 mm in 3rd year, 553 mm in 4th year and 738 mm in 5th year. The growth rate of *T. tor* appear to be faster in Tawa reservoir as compared to Narmada species (196 to 565 mm in I to VI years).

Observations on breeding and recruitment

The observations on the availability of fish eggs, larvae and fry were made during monsoons (Jul-Sep) using Midnapore shooting nets (1/8" mesh). Jaunpur scoop net was also operated in the shallow marginal areas of the reservoir. In 1995, the breeding occurred in the second week of July when the inflow abruptly increased from 124 (10th July) to 435 million m³ (11th July). Fry of major carps, *C. catla* (30-40 mm), *C. mrigala* (20-30 mm) and *L. rohita* (25-35 mm) were collected from intermediate and lentic sectors in August and September, 1995.

In 1996, the reservoir water level was low (343 m) in July which prevented the migration of major carps to the upper reaches. The operation of shooting net did not yield any spawn. However, fry of major carps (11-25 mm) were collected by Jaunpur net at Banglapura during the first fortnight of August. The fish failing to ascend appear to have bred in the reservoir itself in late July. Among major carps, *C. catla* (20-25 mm) was dominant (79.4%) followed by *C. mrigala* (11-13 mm) 11.8% and *L. rohita* (14-15 mm) 8.8%. Advanced fry of major carps were collected at Banglapura even in late September. *C. catla* (40-45 mm) was dominant (56.3%) followed by *C. mrigala* (30-53 mm) 25.0% and *L. rohita* (44-50 mm) 18.7%.

In 1997, monsoon was delayed and breeding occurred in late July. Post-larvae (8-10 mm) of major carps (Catla/Mrigal) were collected in late July and fry of *C. catla* (40 mm) and *L. rohita* (29 mm) in early August.

The studies indicated that the breeding grounds of major carps in the lotic sector come under the submergence at a higher water level above 350 m. The timely monsoon inflow in July and high reservoir water level are the key factors for successful breeding and recruitment.

Impact of stocking on fish yield

Tawa reservoir is being stocked regularly from 1979-80 with fry/fingerlings of major carps (Fig. 12). In the initial stages till 1986-87, the annual stocking rate was low (59 nos/ha) and the fish yield was poor (4 kg/ha). The stocking rate was raised during 1987-88 to 1996-97 to 192 nos/ha. The fish yield gradually increased from 10 kg/ha to 24 kg/ha. During 1997-98 and 1998-99, the reservoir was stocked @ 221 nos/ha and the yield is likely to go up further in the following years. It was also observed that stocking with greater emphasis on *L. rohita* (50%) till 1986-87 did not improve the fishery but higher stocking rate of *C. catla* (41-48%) from 1987-88 onwards significantly enhanced the yield (Table 10). This clearly shows the suitability of the ecosystem for catla. *C. mrigala* showed some improvement in 1996-97 and 1997-98. The fishery of *L. rohita* has not improved in spite of good stocking support (Fig. 13). This calls for reduction in stocking of rohu. Stocking of *T. tor* should be undertaken as a measure of conservation of this important fish and also to utilize the molluscs and insects.

Maximum sustainable yield (MSY) and optimum fishing effort (fmsy)

Using Schaefer's model, the maximum sustainable yield (MSY) with optimum fishing effort (fmsy) in a year was worked out for Tawa reservoir. The data of annual fish yield and annual effort in terms of weight of nets from 1994-95 to 1998-99 were taken into account. The equation can be expressed as :

$$Y(i) = 0.842 f(i) + (-0.0005) f(i)^2$$

where $Y(i)$ = annual fish yield (t), $f(i)$ = annual effort in weight of nets (t), 0.842 = intercept (a) and -0.0005 = slope (b).

The equilibrium annual fish yield was calculated which increased with the increase in effort. But after attaining 354.5 t (MSY) with the optimum effort of 842 t (fmsy), the yield declined despite the increase in effort subsequently.

Management

The Government of Madhya Pradesh categorized reservoirs into 3 groups for the purpose of management : a) reservoirs upto 40 ha are to be leased out to co-operatives, groups and individuals of scheduled castes, tribes and other sects below the poverty line, for a period of 5 to 10 years, b) reservoirs above 40 ha and upto 2000 ha are to be developed and managed by the Fisheries Department and c) reservoirs above 2000 ha are to be developed and managed by the State Fisheries Corporation.

The fishing activities in Tawa were initiated immediately after the formation of the reservoir in 1975. Initially the reservoir was under the State Fisheries Department, but came under the administrative control of M.P. State Fisheries Development Corporation since 1979. The corporation conducted fishing till 1985 (6 years) hiring fishermen on daily wages. During next 8 years (till 1993-94) the reservoir was leased to a contractor on the basis of a tender. In 1994-95, on the basis of auction the reservoir was leased to a Fishermen Co-operative Society viz. Aadarsh Machhua Sahkari Samiti, Bhopal for one year for Rs. 30.8 lakh with the right to exploit and market the fish catch. In 1995-96, the commercial fishing could not be started after the closed season (15 Jun-15 Aug 95) due to some administrative problems of the Fisheries Corporation.

Table 10. Stocking and its impact on fish yield in Tawa reservoir

Period	Annual Stocking (lakh)	Catla (%)	Rohu (%)	Mrigal (%)	Rate of stocking (nos/ha)	Average fish yield (kg/ha)	Managing Agency
1979-80 to 1986-87	7.2	37	50	13	59	4	State Fisheries Corporation
1987-88 to 1996-97	23.5	41	39	20	192	10	— " —
1997-98 to 1998-99	27.0	48	24	28	221	24	Tawa Matsya Sangh

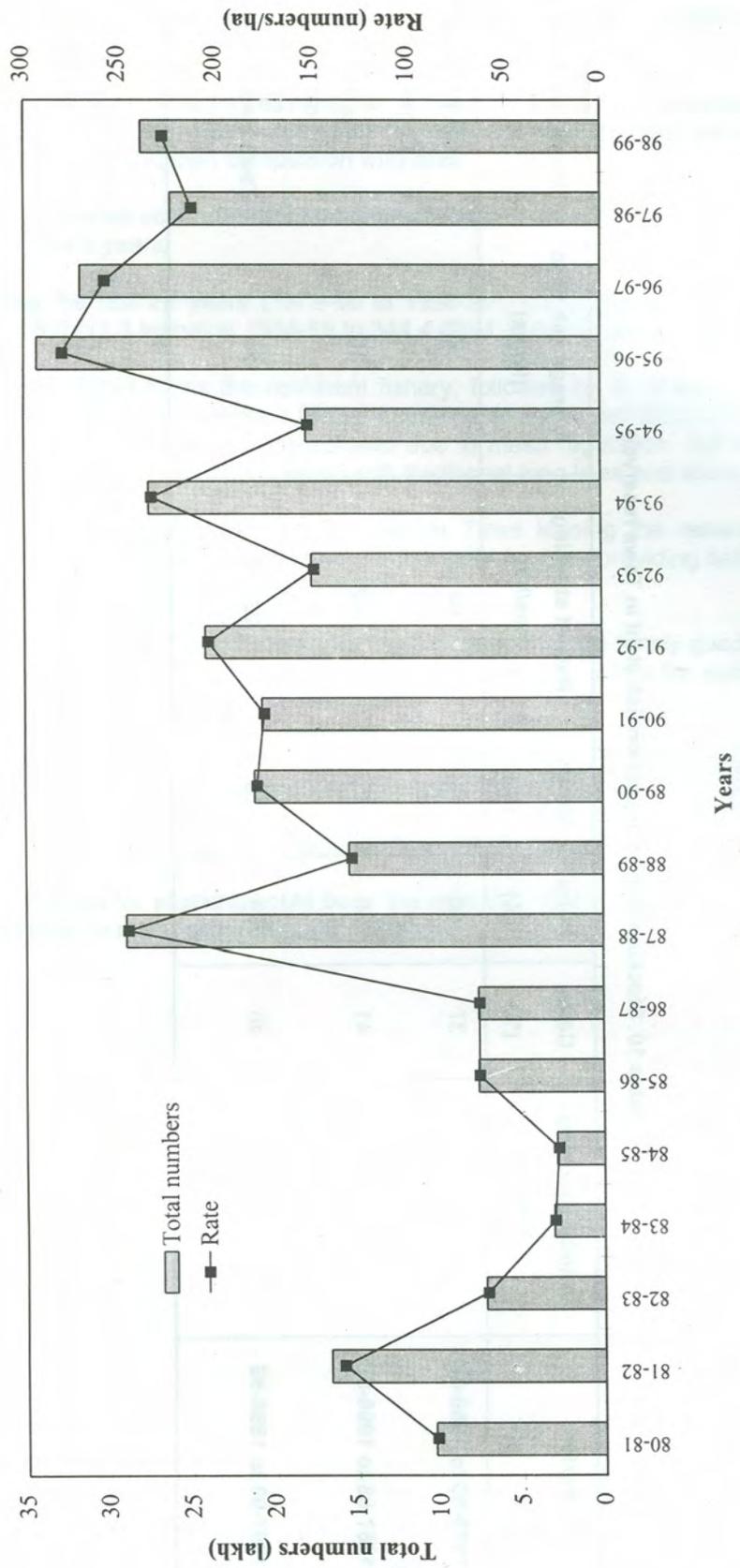


Fig. 12. Fish seed stocking in Tawa reservoir

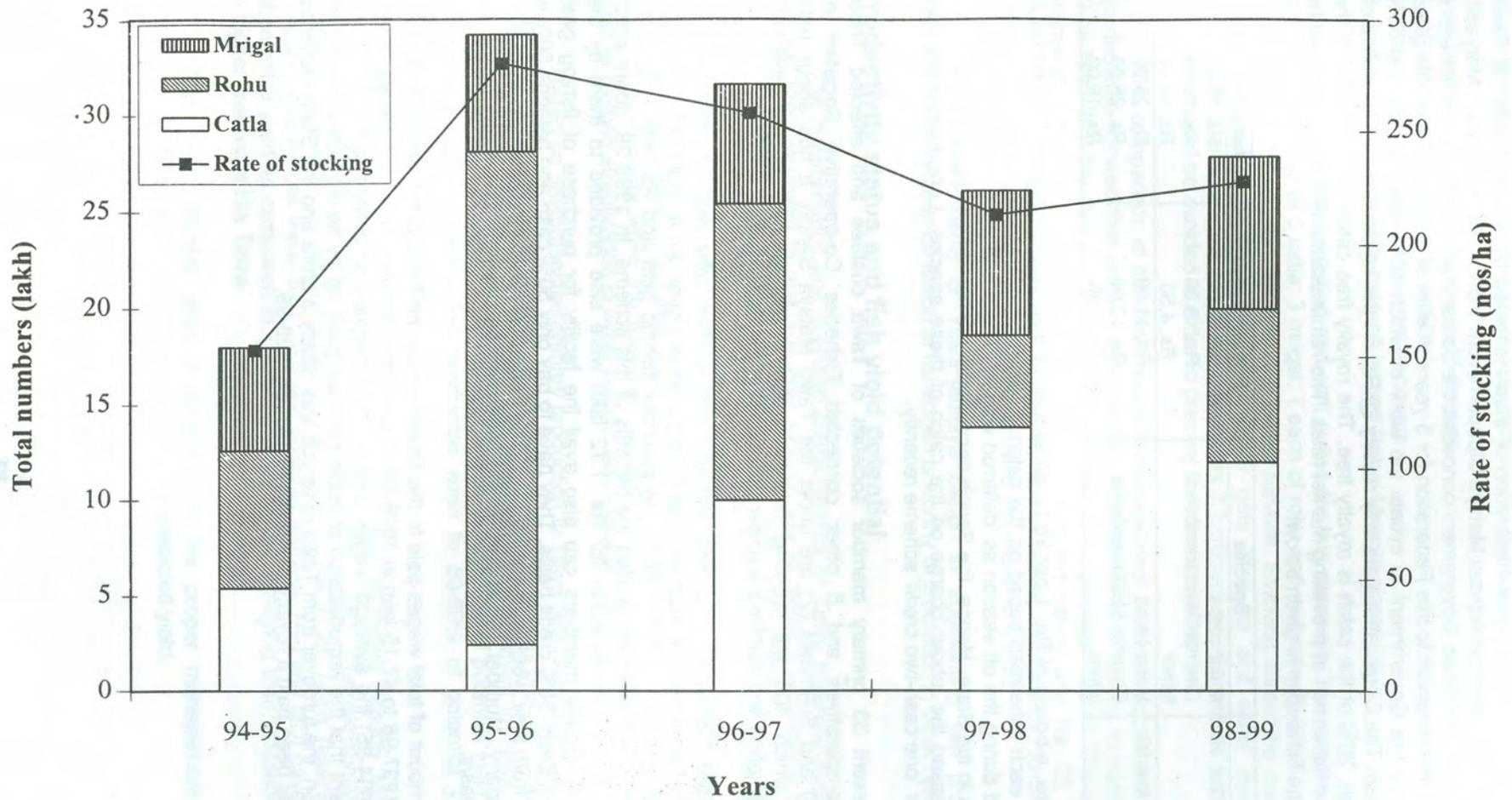


Fig. 13. Fish seed stocking with species composition and rate of stocking in Tawa reservoir

In October, 1996 an Apex Federation of tribals affected by the inundation of Tawa reservoir, The Tawa Visthapit Adivasi Matsya Utpadan avum Vipnan Sahkari Sangh Maryadit, Kesla, was formed. The State Government conceded the demand of oustees to give the entire fishing rights of the reservoir to this Federation for 5 years. A sum of Rs. 6 lakh was also given to the Sangh by the Government to initiate the work of which 50% was subsidy and 50% interest free loan. The Corporation gets only royalty @ Rs. 6/- per kg on 80% of the total catch from the Sangh, 20% of the catch is royalty free. The royalty free catch is purchased by the Sangh from the fishermen at prevailing market rates. The remuneration (Rs./kg) being paid by the Sangh to the fishermen is given below:

Period	Species	Royalty catch	Royalty free catch
16 Aug to 01 Oct. 98	Major carps	Rs. 8.75	Rs. 15.00
	<i>Channa/ Mastacembelus</i>	Rs. 13.00	Rs. 28.00
	Minor	Rs. 4.50	Rs. 12.00
02 Oct. to 31 Mar 99	Major carps	Rs. 11.00	Rs. 26.00
	<i>Channa/ Mastacembelus</i>	Rs. 12.00	Rs. 28.00
	Minor	Rs. 5.00	Rs. 15.00

Besides, a bonus of Re. 1 per kg for all species is also paid separately. The bonus is calculated for each fishermen based on the catch obtained by him during the fishing season and distributed during the off season as 'deferred wages'. There is a good market for murels and spiny eels in the State. Hence, the Sangh encouraged the fishermen to operate long lines and also increased the labour charge on the catch of these species. Long-lines were also provided under 'one cash-two credit' scheme recently.

At present 33 primary member societies of Tawa oustees and affected Tribal Fishermen Co-operatives and 5 other connected Fisheries Co-operative Societies of Tawanagar (3) and Sukhtawa (2) are under the Tawa Matsya Sangh. It has about 1042 members, of which 400 are working fishermen. Entire management of the reservoir, production, marketing and stocking is under the control of the Federation.

The Apex Federation has also started some welfare schemes for the fishermen. Under IRDP, the fishermen are supplied with fishing craft and gear. An amount of Rs. 12,000/- is given as soft-loan, of which Rs. 8000/- to purchase fishing gear and Rs. 4000/- for craft. During 1997-98, 137 fishermen availed the benefits of this scheme. In 1998-99, gears worth Rs. 9.20 lakh and 28 boats worth for Rs. 1.12 lakh were also provided to them by the Federation. The society members can also avail the facility for purchase of fishing gear material on 50% cash- 50% credit basis. They have to pay only 50% cash and balance 50% is to be adjusted from their weekly payments. The Federation procures webbings from M/s. Garware Company, Mumbai and supply to the fishermen on payment of full amount on no profit no loss basis.

The amount of total wages paid to the fishermen by the Federation has gone up from 30.44 lakh in 1997-98 to 47.15 lakh in 1998-99. Prior to the formation of Tawa Matsya Sangh (1990-91 to 1994-95) the average wages paid to the fishermen amounted to Rs. 6.82 lakh only. It is evident that the remuneration of fishermen has gone up by seven times. Under the Apex Federation, the turnover from Tawa reservoir was nearly a crore and the State Fisheries Corporation has been paid a royalty of Rs. 32.79 lakh till 1998-99.

The conservation measures that are being followed in Tawa are :

- a) Closed season from 15 June to 15 August
- b) Mesh regulation (min. 50 mm bar)
- c) ban on the use of monofilament webbings
- d) ban on catching of catla below 2 kg and Rohu/ Mrigal below 1 kg.

Catla is well established and well suited for this reservoir. The species for stocking could be in the ratio of 5 catla: 3 mrigal: 1 each of rohu and mahseer @ 300 fingerlings/ha/ in the size range 75-100 mm for ensuring better survival. Stocking should be done preferably during October-November when the reservoir gets filled up and water levels stabilize. Intermediate sector is ideal place for stocking as it harbours good plankton population . The dam zone should be avoided in order to prevent their escapement.

The comparison of different modes of management practices adopted in Tawa in last two decades showed that under departmental management and leasing to contractor (1979-80 to 1995-96), the fish production was low (84-176 t ; average 120 t). The average daily income of a fishermen engaged in the fishing during this period was Rs. 25. But with the advent of Tawa Matsya Sangh 1996, the production increased significantly (93-344 t ; average 228 t) and the daily earnings of the fishermen also increased to Rs. 73.

The achievements of Tawa Matsya Sangh in augmenting fish production and improving the economic condition of fishermen is worthy of emulation in other reservoirs.

Productivity status and fish yield potential

The morphometric and drainage characteristics of Tawa reservoir such as its large size and low catchment to reservoir area indicate low to medium productivity potential. The catchment, though has some forest cover, has been intercepted by the Sarni reservoir upstream of Tawa reservoir. The amount of flood water inflows in relation to its storage capacity is also low at 1.7, showing limitation in the loading of organic matter and nutrients.

Among chemical features, organic matter of soil, alkalinity of water are in medium range of productivity while the essential nutrients are in low productive range. The weak summer oxygen stratification in water column also indicates low to medium productivity.

Based on phytoplankton primary production in Tawa reservoir, a judicial consideration of fish yield potential is ascertained to be of 0.2% of GPP (Gross primary production) which yields 84.0 kg of fish/ha/yr. At present with provisional management in Tawa reservoir, the maximum fish yield obtained is 28 kg/ha/yr, which is only 32% of potential yield. There is still enough scope of increasing fish production even to 50-60% of potential yield following scientific management norms.

Besides, the potential fish yield (PFY) was also estimated through 'Morpho-edaphic index' - MEI (Ryder model), 'Morpho-drainage index' - MDI (Ramakrishniah, 1991) and biomass calculation (Waldichuk, 1958). The PFY (kg/ha/yr) of Tawa reservoir estimated through these indices were 30.0, 20.0 and 95.0 respectively. MEI and MDI gave lower values of potential yield as compared to Trophodynamic model signifying their limitations particularly in bigger reservoirs like Tawa.

The yield potential gives a guidance for the proper management. With better management the fish yield could be higher than the predicted yield.

Production potential in Tawa reservoir (kg/ha/y)

MEI	MDI	0.2% GPP	Bio-mass
30.0	20.0	84.0	95.0

Recommendations

Yield potential estimated from different models showed that the potential of Tawa reservoir is low to medium. The low ratio of catchment to reservoir area (30) and low drainage index (4) indicate poor loading of allochthonous inputs limiting productivity. This has been demonstrated by the poor performance of rohu in spite of stocking support. The oligotrophic conditions of the reservoir are not favourable for rohu.

Catla is well established as in other oligotrophic reservoirs and is the mainstay of the fishery. As the natural recruitment is undependable, it should form the main component of the stocking.

Due to mesh regulation large segments of endemic populations such as small and medium carps and carp minnows are left unexploited, leading to their built-up. It is desirable to exploit them through shore seines and small-meshed gill nets. The period of such operation should be during the period of low water levels (February-June) under departmental supervision. This will add to the overall fish production and also minimise their competition with the economic species.

Due to large number of gill nets of mesh bar 50-90 mm, catla of 2 and 3 age groups are being exploited intensively resulting in high mortality rate (0.688). The gill nets of bigger meshes (100-120 mm bar) should also be introduced in the commercial fishing to exploit larger size groups.

In view of significant achievements of Tawa Matsya Sangh in augmenting fish production and improving the socio-economic status of fishermen, the same system may be encouraged.

The submerged obstructions like tree trunks and boulders pose considerable problems in the operation of gill nets resulting in a large reservoir area as non-fishing territory. The Fisheries Department has cleared only an extent of 7352.73 ha area. It may not be practicable to clear all the areas of the reservoir. But, exposed areas during low water levels may be cleared to facilitate fishing.

The plankton is in moderate concentration with dominance of zooplankton. The minnows are likely to compete for this food niche with catla. Hence, the need to exploit weed fishes under departmental supervision.

Among macro-benthos, dipterans, gastropods and bivalves are important. This food niche is left unutilised to a great extent by the existing fish populations. Inclusion of mahseer which is at low stock density would be useful in the utilization of bottom insects and molluscs and also help in the conservation of this important fish. *Pangasius pangasius* is also a good species for utilising molluscs. However, procuring the seed of this fish is a difficult task.

The breeding of major carps has been observed in Tawa. The natural recruitment of catla, though on a limited scale, was observed in the reservoir. But the breeding and recruitment are subjected to the vagaries of monsoon and could not be relied upon. Hence, it is essential to stock the species on continuing basis.

The reservoir should be stocked annually with good quality seed of major carps @ 300 fingerlings/ha in the ratio 5 C: 3 M: 1 each of rohu and mahseer. The size of fingerlings should be at least 75-100 mm. Stocking should be done preferably in October-November in intermediate sector. Dam zone should be avoided as far as possible to prevent their escapement. The shallow lotic region of the reservoir may be protected, specially during monsoons for better recruitment.

The Satpura National Park (SNP) under the Forest department is insisting on a ban on fishing in some parts of Tawa reservoir. Besides, SNP, Bori sanctuary and Pachamarhi sanctuary are also under the forest department and they together cover a major area of the reservoir. The issue should be sorted out so that forest sanctuaries and fisheries activities could run simultaneously in the best public interest.

Summary

Tawa (20,055 ha), an irrigation reservoir was constructed across river Tawa, the main tributary of river Narmada in 1975.

The catchment area of 5982.9 sq. km, has predominantly forest cover. The ratio of catchment to reservoir area (30) is low.

Shore development index (5.6) indicates that shore line is not much irregular to provide Bays and Coves. The volume development index, being less than 1, indicated that the basin is convex towards water.

Peak inflow generally occurred during July- September. The flushing rate (1.7) is moderate.

Soil condition with organic carbon (0.63%), total nitrogen contents (0.047%), available phosphorus (0.57 mg/100 g) and free calcium carbonate (2.9%) indicated low to medium productivity.

Water quality with values of pH (7.9), DO (6-8 mg^l⁻¹), total alkalinity (46-97 mg^l⁻¹), total hardness (48-96 mg^l⁻¹), specific conductivity (75-140 μScm⁻¹), phosphates (Tr.- 0.09 mg^l⁻¹) and nitrates (0.02-0.22 mg^l⁻¹) also showed the low to medium productive nature of the reservoir.

Thermal stratification was observed during summer between 7-8 m depth. Weak oxycline occurred during March-May.

Plankton exhibited two peaks with predominance of zooplankton. Fifty two species of zooplankton with rotifers (23) and cladocerans (18) and 48 species of phytoplankton with dominance of green algae (18), diatoms (15) and blue-green algae (11) were recorded. Macro-benthic population was moderate and constituted by dipterans (44.5%) and gastropods (39.7%). Diatoms (68-84%) were predominant in periphyton with a summer pulse in June and winter pulse in December.

Macrophytes were poor with occasional occurrence of *Hydrilla* and *Vallisneria*.

The water quality and the abundance of biotic communities indicated the oligotrophic condition of the reservoir.

Forty three fish species belonging to 10 families and 26 genera were recorded from Tawa reservoir. Silver carp was recorded for the first time from the reservoir which is a matter of concern in view of its known competition with catla.

Fishing started soon after the formation of the reservoir. It was leased to Tawa Matsya Sangh in 1996 for 5 years.

During the last 20 years (1979-80 to 1998-99), the annual fish production of Tawa ranged from 16.5 t (1.3 kg/ha) in 1984-85 to 344.4 (28.1 kg/ha) in 1998-99.

C. catla (71%) forms the dominant fishery, followed by *C. mrigala* (8.9%), *L. rohita* (1.9%) and *T. tor* (0.6%). Indigenous fishes (Local major and minor groups) formed 7 to 25%. Minnows (2.7%) are by and large unexploited due to mesh regulation. Gill nets (50-100 mm bar) are mainly used for exploitation along with traditional long lines and shore seines.

The 'Co-operative movement' initiated in Tawa leasing the reservoir to an Apex Federation proved fruitful as it augmented the fish yield besides providing better remuneration and other welfare programmes to the fishermen.

Observations on pre-recruitment of fish indicated that the timely good monsoon inflow in July and higher water level (> 350 m) are main governing factors for successful breeding and recruitment of major carps in this reservoir.

Stocking in Tawa reservoir was low in initial stage with hardly any impact on the fishery. With the increase in stocking rate, the fish production also improved. Despite heavy stocking, *L. rohita* did not come up in this reservoir. The retrieval of major carps in relation to stocking was very poor. It was 4% in case of catla, 1% mrigal and 0.1% for rohu.

The species for stocking could be in the ratio 5 C : 3 M : 1 each of rohu and mahseer @ 300 fingerlings/ha in the size range 75 - 100 mm.