LIMNOLOGY AND FISHERIES OF THE TUNGABHADRA RESERVOIR

Bulletin No. 13

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CENTRAL INLAND FISHERIES RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

BARRACKPORE, WEST BENGAL

INDIA

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by

A. David, P. Ray, B.V. Govind
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FOREWORD

The Report entitled " Limnology and Fisheries of the Tungabhadra Reservoir" incorporates the work of the Lacustrine Unit of the Central Inland Fisheries Research Institute conducted during the period October 1963 to September 1965. This is the first exhaustive report of its kind in the country covering various aspects of the limnology of a storage reservoir, which have a bearing upon rendering such water bodies productive for fish. There is great scope for the development of the fisheries of the Indian reservoirs of which there occur more than 300 in the country. This report will have served its purpose if it leads to adoption of concrete and purposeful steps by the authorities concerned towards rendering the Indian reservoirs really productive.

Dr. B.S. Bhimachar, ex-Director of the Central Inland Fisheries Research Institute, had set up the Lacustrine Unit and had envisaged the fish productive potentialities of multi-purpose storage reservoirs. The keen interest which Dr. Bhimachar took in the progress of work of the Tungabhadra Dam Unit and facilities which he offered have enabled conduct of investigations on a comprehensive scale and accumulation of useful data on various limnological and fishery biological aspects possible, the like of which are not available in respect of any reservoir in the country.

The Lacustrine Unit, to which this work relates, worked under the immediate technical guidance of Dr. A. David, Senior Research Officer. Dr. David conducted the investigations with the assistance of a team of young workers notably Sarvashri P. Ray, B.V.Govind, K.V.Rajagopal, R.K.Banerjee, K.Gopinathan and P.M.A. Kadir, whose respective contributions have been mentioned elsewhere in the report. The present report and the work it portrays are the result of co-operative endeavour of the above-stated workers.

V G Jhingran
(V.G.JHINGRAN)
DIRECTOR

November 13, 1969

Central Inland Fisheries
Research Institute,
Barrackpore.

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p. (iv), line 17 add " , " after RECRUITMENT

p. 10, para 2, line 8 delete " , " after "below"

p. 10, para 4, line 12, for 'of 21', read 'of No. 21'

p. 15, para 2, line 16, for 'control', read 'central'

p. 17, para 2, line 7, for "strewn boulders" read "boulder strewn"

p. 17, para 2, line 11, read "contributes" for "contribute"

p. 18, para 1, line 3, substitute " , " for " ; "

p. 23, para 2, line 9, for 'drawn down' read 'draw-down'

p. 24, para 3, line 5, for 'increasing' read 'increased'

p. 26, para 2, line 1, for 'silt ladden' read 'silt-laden'

p. 26, para 3, line 2, for "fluviatille" read 'fluviatile"

p. 30, para 2, line 5, for 'ranged', read 'range'

p. 30, para 2, line 5, for 'from 2', read 'from 1 to 2'

p. 30, para 3, line 4, for 'and I' read 'and zone I'

p. 31, para 3, line 6, for 'support' read 'supports'

p. 35, para 1, line 1 & 2, for 'Zone I, second', read 'Zone I, the second'

p. 40, para 3, line 3, for 'there', read 'their'

p. 40, para 3, line 8, for 'manurial' read 'manurially'

p. 53 line 7, for '<u>danicenius</u>' read '<u>daniconius</u>'

p. 53 line 20, for '<u>amphibia</u>' read '<u>amphibius</u>'

p. 57, para 1, line 8, for 'was' read 'is'

p. 63, para 2, line 13, for "scarce the", read 'scarce, the'

p. 65, para 4, line 2, for "species but its", read "species, its"

p. 66, para 3, line 12, for "water land", read "water level"

p. 77, para 3, line 4, for 'August & their', read 'August and their'

p. 83, para 3, line 1, for '<u>Glassogobius</u>', read '<u>Glossogobius</u>'

p. 84, Title for "GROWTH AGE AND", read "AGE AND GROWTH"

p. 84, para 1, line 1, for 'The age growth', read 'The age and growth'

p. 87, para 1, line 9, for 'wing', read 'using'

p. 87, para 2, line 3, for 'Rajahundry' read 'Rajahmundry'

p. 88, para 2, line 2, for "reservoirs", read "'reservoirs'"

p. 90, para 2, line 6, for "year" read "years"

p. 90, para 3, line 4, for "Rangood', read 'Rangoon'

p. 90, para 3, line 12, for 'Uduvalas', read 'Uduvalai'

p. 90, para 4, line 2, for 'major medium', read 'major and medium'

p. 91, para 3, line 3, for 'reservoir, number', read 'reservoir and number'

p.102, para 2, line 8, for 'abandon', read 'abandoned'

p.103, below Table 19, para 2, line 2, for 'reservoirs', read 'reservoir'

p.103, below Table 19, para 2, line 4, for Shrunken', read 'shrunken'

p.105, para 2, line 7, for 'As removed', read 'Removed'

p.112, para 3, line 3, for 'alove' read 'alone'

p.112, para 3, line 13,for 'on' read 'or'

p.114, para 1, line 13,for 'Institute for',read 'Institute arranged for'

p.124, para 2, line 2, for 'are' read 'were'

p.126, para 1, line 2, for "meshed", read 'meshes'

p.128, Table 24, last line, for '_M. punctatus_' read '_M. maydelli_'

p.132, para 5, line 4, for 'rope absence', read 'rope, absence'

p.145, para 3, line 2, for 'mm in maximum' read 'mm (maximum)'

* p.151, para 2, line 2, for 'reservoirs', read 'reservoir's '

p.151, para 2, line 3, for 'dissoved', read 'dissolved'

p.152, para 1, line 6, for 'and' read 'an'

p.156, para 3, line 8, for 'riches' read 'richest'

p.157, para 1, line 7, for 'net', read 'nett'

p.157, para 2, line 4, for 'chatches', read 'catches'

* p.147, Table 30, line 4, for 'as well ratios', read 'as well as ratios'

p. 160, para 1, line 5, for 'are migratory', read 'are no migratory'

p. 161, para 1, line 7, for 'interesting Pseudeutropius', read 'interesting that Pseudeutropius'

p. 162, para 2, line 1, for 'Basayanna' read 'Basavanna'

p. 165, para 4, line 7, for 'Nemachius', read 'Noemacheilus'

p. 167, para 3, line 5, for 'Gagetic', read 'Gangetic'

p. 169, para 6, line 2, for 'trammal', read 'trammel'

p. 170, para 5, line 3, for 'stocking', read 'shocking'

p. 170, para 5, line 6, for 'destory', read 'destroy'

p. 171, para 2, line 2, for 'Boards' read 'Board's

p. 171, para 3, line 4, for 'fish, disposal', read 'fish and its disposal'

p. 171, para 5, line 2, for 'centrelly', read 'centrally'

p. 171, para 6, line 6, for 'samples', read 'samplings'

p. 174, para 3, line 5, for 'Brachinus', read 'Brachionus'

p. 176, para 3, line 4, for 'Mid-June', read 'mid-June'.

p. 177, para 1, line 1, for 'fishermen of', read 'fishermen at'

p. 182, para 1, line 7, for 'Nemachilus' read 'Noemacheilus'

p. 182, para 2, line 4, for 'or such', read 'or those'

p. 185, para 1, lines 7 & 8, for 'mg' read 'gm'

INTRODUCTION

Natural freshwater lakes comparable to those in North America, Africa or Europe are absent in India, the freshwater lakes of Kashmir, Uttar Pradesh, Assam and Madras being small, hilly lakes or jheels and shallow swampy river inundations. The country is, however, rich in storage reservoirs created for irrigation and power generation, the last three 5-year plans having further increased the number of such reservoirs. There are, at least, 295 reservoirs in India covering a water spread area of about 12,00,000 ha. These storage reservoirs can yield, with little or no investment, good quantity of fish crops by proper management practices and production and exploitation techniques. Approaches made elsewhere towards production of fish in natural lakes cannot be applied *in toto* to such reservoirs due to great fluctuations in their water levels and functional utility of the stored water. Besides, fish fauna and their biological activities are determined by the characteristics of the river affected as conditions are not uniform from reservoir to reservoir. The experience gained by an integrated study of the Tungabhadra Reservoir is now expected to help the development of other reservoirs in India for utilising similar stored waters for fish production.

Though fishery surveys for possible effects of high dams on fish life in river drainages have been conducted in several projects before construction of dams (Hirakud, D.V.C., Rihand, Chambal, Nagarjunasagar, etc.) and the necessity of fish ways for protection of migratory stocks of fish not felt in them, almost nothing is known as to how the indigenous fish fauna of a flowing river may respond to the newly created stagnant reservoir environments. Though management and developmental practices on two reservoirs in Madras State have been studied for limnological conditions, fish life as a whole is not correlated therewith. This report attempts to fulfil (within the limitations imposed during studies) this lacunae as the reservoirs in India have generally remained undeveloped and their potentiality for fish population not fully appreciated.

DESCRIPTION OF THE DAM AND RESERVOIR

The Tungabhadra Dam is situated 5 km from Hospet in Bellary District, Mysore State, at the old Mallapuram village site, the geographical location being 76° 20' 10" east longitude and 15° 15' 49" north latitude. The twin rivers, the Tunga and the Bhadra that originate in the vicinity of Varaha Parvatha in the Western-ghat range of mountains in Chickmagalur District, unite at Kudli some 80 km from the origin. The length of the Tungabhadra river from the point of confluence of the Tunga and the Bhadra to its merger with the Krishna in Andhra Pradesh is 650 km. The catchment area of the river above Mallapuram is 28,168 sq km of the total of 69,470 sq km of the entire river system. The river is chiefly influenced by the South-West monsoon, the annual rainfall varying from 50 cm at the dry-Maidan dam site to as high as 765 cm in the wet 'Malnad', Western ghat region, with an average of 104 cm (41 inches) in its catchment. Two minor rivers - the Vedavathi, part of its stretch being known as the Hagari, and the Varada join the Tungabhadra river along with several minor but perennial mountain streams in the Shimoga and Chickmagalur Districts. A storage reservoir on the Bhadra and the Tunga anicut (weir) on the Tunga were completed during the last 10-15 years. A number of medium reservoirs like the Vanivilas sagar and Anjanapur and several large tanks like the Shanthisagar and Madag are situated on the minor rivers or streams draining into the Tungabhadra river.

The main dam is a masonry and cement structure of 1731 m with a left flanking composite dam of 463 m in length. The height of the Dam is 49 m (162 ft), the average height above the bed being 35 m (116 ft). There are 33 spill-way gates at the crest of the dam.

Volume development of the reservoir is 0.737 indicating that the lake basin is convex and shore development is 5.251 showing an unusually irregular periphery (Table 1).

Table 1.

Hydrographical features of the Tungabhadra Reservoir

Area	146 sq miles (37,314 hectares)	
Maximum length (effective length)	50 miles (80 km)	
Maximum depth	133 ft (41 meters)	
Mean depth	37.7 ft (9.8 meters)	
Gross Volume	133000 mcft	
Live storage	131000 "	
Maximum flood discharge	3,30,000 cusecs	
Average height of the dam above river bed	116.1 ft	
No. of villages submerged	90	
Shore line (Perimeter)	Level of water (in ft)	Length mile km
	1580	53 85
	1590	58 93
	1600	66 106
	1610	85 136
	1620	149 239
	1630	198 318
	1633	210 337
Maximum outflow	1,48,300 cusecs	(14.8 '64)
Minimum outflow	200 "	(15.3 '65)
Maximum inflow	1,55,858 "	(10.8 '64)
Minimum inflow	3,951 "	(7.6 '65)
Volume development	0.737	
Shore development	5.251	

$$\text{Volume development} = \frac{3(md)}{mxd}$$

where md = mean depth of the lake
mxd = maximum depth of the lake

$$\text{Shore development} = \frac{S}{2\sqrt{a\pi}}$$

where S = length of the shore line and
a = area of the lake.

There are two major power-cum-irrigational canals (low level canals) with an installed capacity of 2,12,900 kw on both the banks; the two power houses on each bank and one at a distance of 22 km on the right bank low level canal are already commissioned. These two canals as well as the high level canal on the right bank total 764 km (466 miles) in the main canals and 1600 km in the distributaries. The project is designed to irrigate 2 million acres (8,08,000 hectares). Ancillary irrigational works, when completed, will allow only 8% of the water to fall into the Krishna finally.

Geographical features of the catchment

Though the major water supply is derived for the reservoir in the Malnad districts, 75% of the catchment is in the dry 'Maidan' part of the Mysore State. Geologically, the catchment, in general, is the 'Archean' type, associated with granite rocks. Both Dharwar schists and peninsular gneisses underlie the catchment's soil mantle. By leaching, and removal of silica, alkalies, lime, etc., laterites are formed on the granitic gneisses, especially in Chickmagalur and Shimoga districts. Lateritic soils and gravel are found in these areas. Light yellow and red soils are found elsewhere, the latter predominating mostly in Maidan areas. Iron oxides are found in a diffused condition in these soils. Black soils predominate in the catchment below Harihar where erosion is high due to sparse vegetative cover.

The orogenic and minerogenic materials from the main catchment as well as the submerged area influence the silt and nutrient content of the reservoir. The surrounding hills are rich in iron ores, haematite and limonite being mined heavily. Red ochre is also removed from the Sandur ranges. Bababudan hills in Chickmagalur district supply ores containing 60% iron. Manganese ores are found in Shimoga and Chitaldurg schist belts. Crystalline limestones as chief components of Dharwar schists are noticed elsewhere in the catchment.

The base status of the black soil is high with 40-60% of exchangeable calcium, degree of alkalisation being below 25%. The Tungabhadra river water has a tendency to ameliorate the poor soil conditions by washing down carbonates and other salts. The weathered rock below the soil is pervious to percolating water.

Silt deposition within the reservoir is high, which has reduced the capacity of the reservoir by 13.5% in its first decade of existence. Surface area, however, remains almost the same, though several silty islands and bars are being formed within the reservoir bed. At the river's junction with the reservoir near centre A (Mudalighatti), where there is a sudden check of water flow in the middle of the reservoir, such deposition appears to be heavy as silt bars are rising. The main reservoir portion (Zone IV) and transition Zone II are somewhat free of silt, but sand deposition is noted in patches in these zones. At places, soft silt is 3.0-3.6 m (10-12 ft) in depth. The flow of the river being felt as far down as Tambrahalli Bay in April-June (Sketch map 1) with the reduction in level to 1595-1590 feet, silt deposition is reduced to one meter or less in depth.

The catchment of the Tungabhadra - especially in the main valleys of the Tunga and the Bhadra, possesses the finest forests of the state. The main Malnad, with its high rainfall together with the mountain ranges and slopes of the high peaks of Westernghats, contributes to the evergreen forests, which gradually yield to the deciduous forests surrounding the reservoir in the Maidan belt. The reservoir receives its water supply from these humid forests and the wet mantles of forest cover. During years of normal rainfall, water retained in the forest and soil mantles is made available over several months checking sudden floods; rains in Maidan areas bring heavy surface run-offs and much silt.

Vegetation is now restricted to the hills forming the reservoir's contour in some of the cultivable and uncultivated wastelands, beds and banks of the main river and streams as also in the pasture lands. The reservoir receives during the rainy season enough humic and other inorganic and organic nutrients from the upper Malnad forests and the cultivated areas around the tail end of the reservoir. Black cotton soils of Shimoga and Dharwar districts also bring in soil washings. The area however is not subjected to high erosion as in the D.V.C belt or elsewhere, though silting appears to be quite heavy. The afforestation and soil conservation measures undertaken in the catchment, and intense cultivation of the commanded area of the Lakkavalli (Bhadra Project) and the Tunga Projects above, further contribute to the enrichment by nutrients of the Tungabhadra reservoir, as overflows from fields manured with heavy inorganic salts ultimately drain into the catchment.

Meteorological and Hydrographical Conditions

The climate at the reservoir site is mainly dry (80.7 to 93.7% humidity). The average monthly maximum and minimum air temperatures range between 31.0 to 39.5°C and 13.8 to 22.3°C respectively (Table 2). One disconcerting feature at the reservoir is the prevalence of high winds. Between early May to end of September, South-West winds reach velocities of 26.39 km/hr and blow almost continuously. Average velocities range from 14.4 to 21.4 km/hr during these months. Between October and March, the North-East winds, though prevalent, are neither as intense nor continuous. The high winds between May and September cause waves of as high as 1.8-2.4 m in the middle, deep portion of the reservoir and 1.2-1.5 m elsewhere, exposing to risk fishing operations and impede observations by coracles and small boats. Average monthly rainfall ranged from 0 to 123.4 cm during 1963-65.

The reservoir, being situated within the tropics, is subjected to intense sunlight. From October to May, usually cloudless skies prevail except for brief durations of cloud-bursts during North-East monsoon from October to December on some days. Between June and September, though rainfall may be poor, the days are mostly cloudy and with the incursion of flood water from early June accompanied by heavy gales, rains and drizzle, temperature falls sharply. Day light varies from 11½ to 12½ hours in December and June respectively.

The reservoir starts filling from the first week of June due to early rains in Shimoga district, and reaches its peak level of 1630 feet by the end of June or early July. In the two years of observations, 1964 and 1965, these levels were reached only at the end of July or early August owing to poor rainfall. Inflow ranged from 1261.8 cusecs daily in March 1965 to a maximum of 65098 cusecs in August 1964. Water level fluctuations were about 38 feet over the year but are expected to be about 50 feet once the high level canal is commissioned. Storage of about 1,30,000 m.c. ft. of water (maximum) is not only dependent upon the rainfall in the catchment, but also drawdown requirements in the irrigational and power canals.

SKETCH MAP - I

TUNGABHADRA RESERVOIR

CONTOUR MAP INDICATING EXTENT OF SUBMERGABLE AND EXPOSED AREAS AT 10 INTERVALS AND LIMITS OF RESERVOIRS CONNECTION WITH RIVER STREAM AT VARIOUS LEVELS.

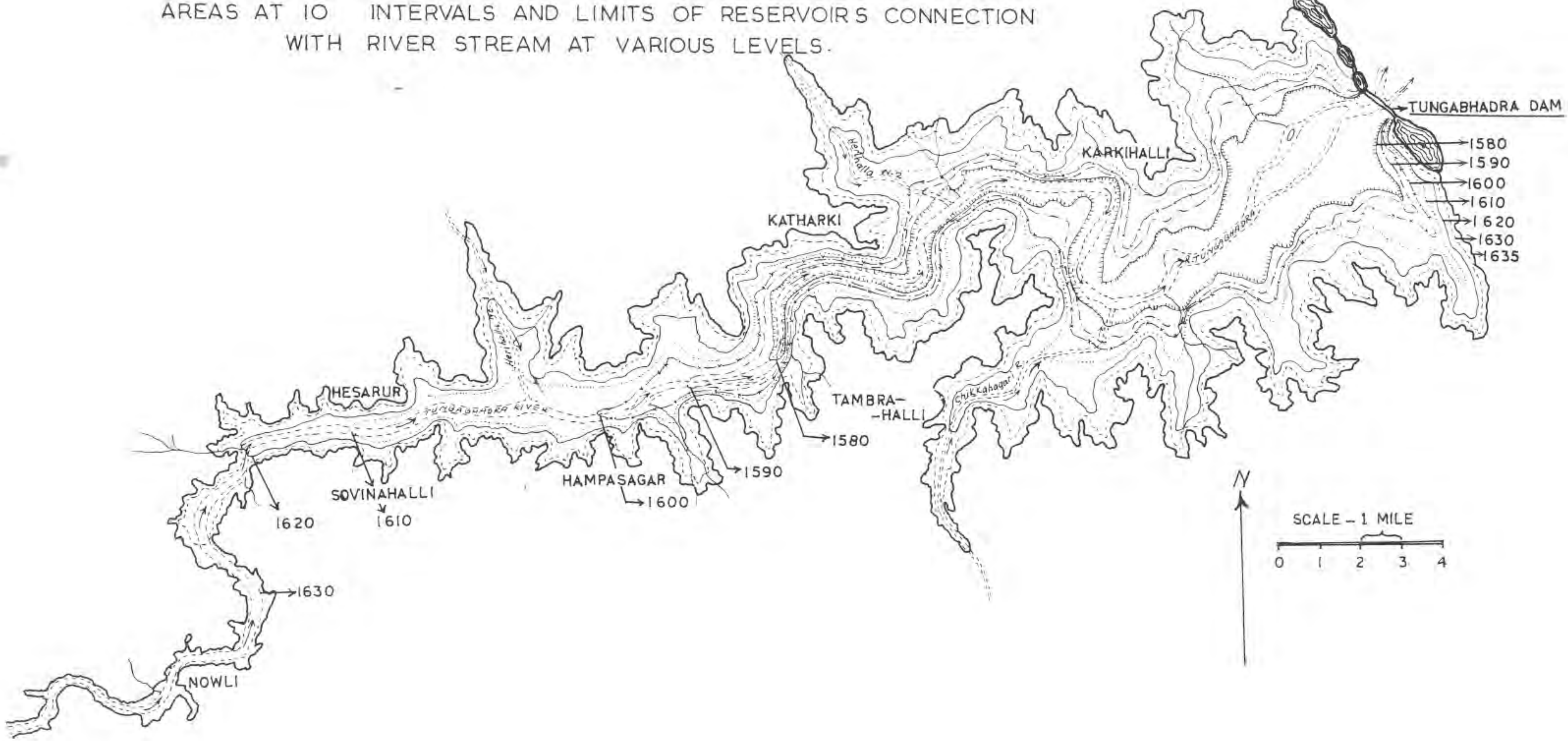


Table 2.

Meteorological data at the Tungabhadra reservoir for the years 1963-'65.

Months	Wind velocity (km/hr)		Rainfall (mm)		Total evaporation (cm)		Air temperature in °C (max)	Air temperature in °C (min)
	Range	Average	Range	Average	Range	Average		
January	8.28- 9.64	9.50	-	-	15.45-16.86	16.3	31.6	13.8
February	9.00-11.66	10.3	-	-	17.97-19.56	18.7	34.8	15.5
March	7.80- 9.96	9.10	0.0- 3.0	1.0	23.19-26.19	24.9	37.5	17.5
April	9.32-12.39	11.0	10.0- 70.5	31.5	23.43-26.0	24.7	39.0	21.8
May	11.82-15.69	14.4	6.09-33.3	15.6	23.95-27.39	26.1	39.5	22.1
June	14.64-20.36	17.5	53.83-106.6	81.3	19.18-19.54	19.4	38.1	22.1
July	17.86-26.39	21.4	28.95-211.01	108.0	13.97-16.11	15.0	33.0	22.3
August	13.76-18.66	17.0	64.8 -102.36	107.4	11.44-16.21	14.0	31.8	22.1
September	11.66-21.24	16.9	61.9 -181.0	123.4	13.47-16.47	15.0	33.1	21.6
October	5.39-18.66	12.8	63.80-217.0	93.6	13.74-19.89	16.2	33.6	19.1
November	7.32-14.96	10.2	3.30- 63.0	22.1	12.26-15.96	15.1	31.5	15.6
December	8.76-12.39	10.6	0.0 - 56.38	19.0	13.21-16.0	14.6	31.0	15.1

A stablised water level at 1630 feet is maintained up to December. In January-February, water level begins to fall by about 3 - 4 inches per day until May-June. In June 1965, almost a dead storage level of 1589 feet was reached. Between the months of January and June, the total water area of the reservoir shrinks from about 137.8 sq miles (35,690 ha) to 42.1 sq miles (10,904 ha), as indicated in Table 3. The marginal inundated areas are exposed and the minimum area of 35 to 42 sq miles refers only to the deep main reservoir portion at the time. The littoral and shallow area, under 10 and 5 feet of water, is also presented in the table; the highly productive (biological) area remains almost constant except at 1600 to 1590 feet levels when there is a sharp fall in available shallow zone. Area under 10 feet of water has varied from 15.62% to 18.3% of the total reservoir spread from 1590 to 1630 feet levels but between 29.54 and 30.63% from 1610 to 1605 feet levels. This indicates that the reservoir is generally shallow, and potentially productive. Since depths ranging from 30 to 50 feet can be expected to be productive in tropical conditions, the reservoir cannot be stated to be a "deep" reservoir from the point of view of fish production. However, the gradual lowering of level between 1630 to 1590 feet over a six-month period is followed by almost an abrupt increase in water levels in June-July by 15 to 20 feet in about three weeks.

Contours and depths

The depths, contours as well as exposed areas during low levels are indicated in Sketch map 1 and Tables 1, and 3. The shore line of the reservoir is highly irregular, and the main reservoir (Zone IV) is trough like averaging 30.8 feet (9.3 m) in depth. This portion covers 49.8% of the total inundable part of the reservoir. Table 3 further indicates the magnitude of the littoral area under 5-10 ft of water (about two meters). The number and extent of bays formed over the periphery especially between Muttukur and Mudalighatti centres (Sketch map 1) offer features not generally encountered in most reservoirs.

Table 3.

Extent of shallow areas of the reservoir in relation to reservoir levels

Reservoir level(ft)	Attained during			Total water area in		Area under				% of area under 10' of water
	1964	1965	1966	sq miles	ha	5 ft depth		10 ft depth		
						sq miles	ha	sq miles	ha	
1633				146	37814					
1630	October '63	January & September		137.8	35690.2	12.5	3237.5	25.3	6552.7	18.3
1625	February	February & December		125.2	32426.8	12.7	3289.3	26.31	6811.7	20.2
1620	March	March	January	112.5	29137.5	13.61	3526.0	26.27	6811.7	23.3
1615	April	March	February	98.9	23615.1	13.66	3537.9	26.51	6863.5	26.8
1610	April	April	March	85.2	22066.8	12.85	3328.1	25.18	6526.8	29.6
1605	May	April	March	72.4	18751.6	12.33	3193.5	22.18	5749.8	30.6
1600	June	April	April	60.1	15565.9	9.85	2551.1	17.94	4636.1	29.7
1595	-	May	May	50.2	13001.8	8.09	2095.3	14.68	3802.1	29.2
1590	-	June	May	-	-	-	-	6.58	1704.2	15.6
1580	-	-	-	-	9194.4	-	-	-	-	-

For purposes of study and easy interpretation, the reservoir was divided into four zones comprising seven centres (Sketch map 2). These four zones and seven centres present specific hydrographical conditions, fishing centres, etc., which occupy definite ecological niches within the reservoir.

Both the Transition Zone II and Shallow Zone III comprising centres B, C, D and E occupy nearly 41.7% of the total reservoir area. While in Zone II, the river course alone is observed during summer months, Zone III becomes nonexistent between March and June as the two major bays of Tambrahalli and Katharki remain exposed. The upper confines of the reservoir, reaching Nowli during maximum levels, recede to Muttukur centre, some 46 km below, during the dead storage levels.

The basin of the reservoir indicating submerged villages, forests, rocky areas, etc., are shown in Sketch map 3. Unlike many newly formed reservoirs, there are no major obstructions for fishing by submerged trees or rocks except in the main reservoir, which is not more than 5% of the minimum water area of the reservoir.

PROCEDURES OF STUDY

Between 1958 and 1963, water samples were examined near the Dam site, close to the boat jetty, in the Deep Water Zone (IV) at Centre G along with plankton and bottom biota. Fish samples by gill nets were also taken by surface gill nets in the vicinity. From September 1963, the seven zonal centres (Sketch 2) were visited regularly once a fortnight and later in 1965 once a month, and samples of water obtained both from the surface (0.5 m depth) and bottom (0.25 m above the substratum). These were analysed for physical and chemical constituents. Plankton samples were obtained at the same stations, 10 to 50 litres of water taken by the Kemmerer sampler being seived through plankton net of 21 bolting silk cloth and preserved in formalin. These were analysed in the laboratory both qualitatively and quantitatively. Littoral samples were obtained by moving an improvised D-type 0.5 metre net through a length of 10 m covering an area of 50 sq m and the invertebrate fauna hand-picked. Bottom organisms were collected through the 9" x 9" (523 sq cm) Ekman's dredge, three to six samples obtained at each centre were seived through No.40 seive. Soil samples were obtained once in two to three months depending upon conditions over the whole period, and analysed in the laboratory for chemical constituents.

Fish production assessments between 1958 to 1963 were based on Hospet fish assembly centre for want of a centralised pooling agency or a market centre, but these figures proved erroneous as only part of the catch brought to the centre was so analysed. Later in 1963 this was corrected and supplemented by a complete wholesale assembly data at Hospet and actual landings along the reservoir at Korlahalli, Hesrur, Hampasagar and Tambrahalli. Sporadic catches at other centres on both flanks and transported elsewhere were also taken into account. In the beginning, fish catches were mainly referable to gill nets, but in 1964 and 1965, shore seines being extensively operated, actual landing grounds became fluid and ranged over the entire riverine stretch. Actual landings, by stratified samplings over the entire reservoir, were therefore computed from the wholesale Hospet and other fish assembly centres, mainly Hesrur, Hampasagar, Tambrahalli and Koppal.

Sizes, weights and species composition of fish were recorded from random samples over the period. Food studies were made by preserving the guts of fishes caught during experimental fishing. Random samples in landings as well as measurements of sizes and weights, form the basis of biological studies. Gonad conditions and fullness and otherwise of food ingested were recorded wherever catches were examined at fishing and assembly centres.

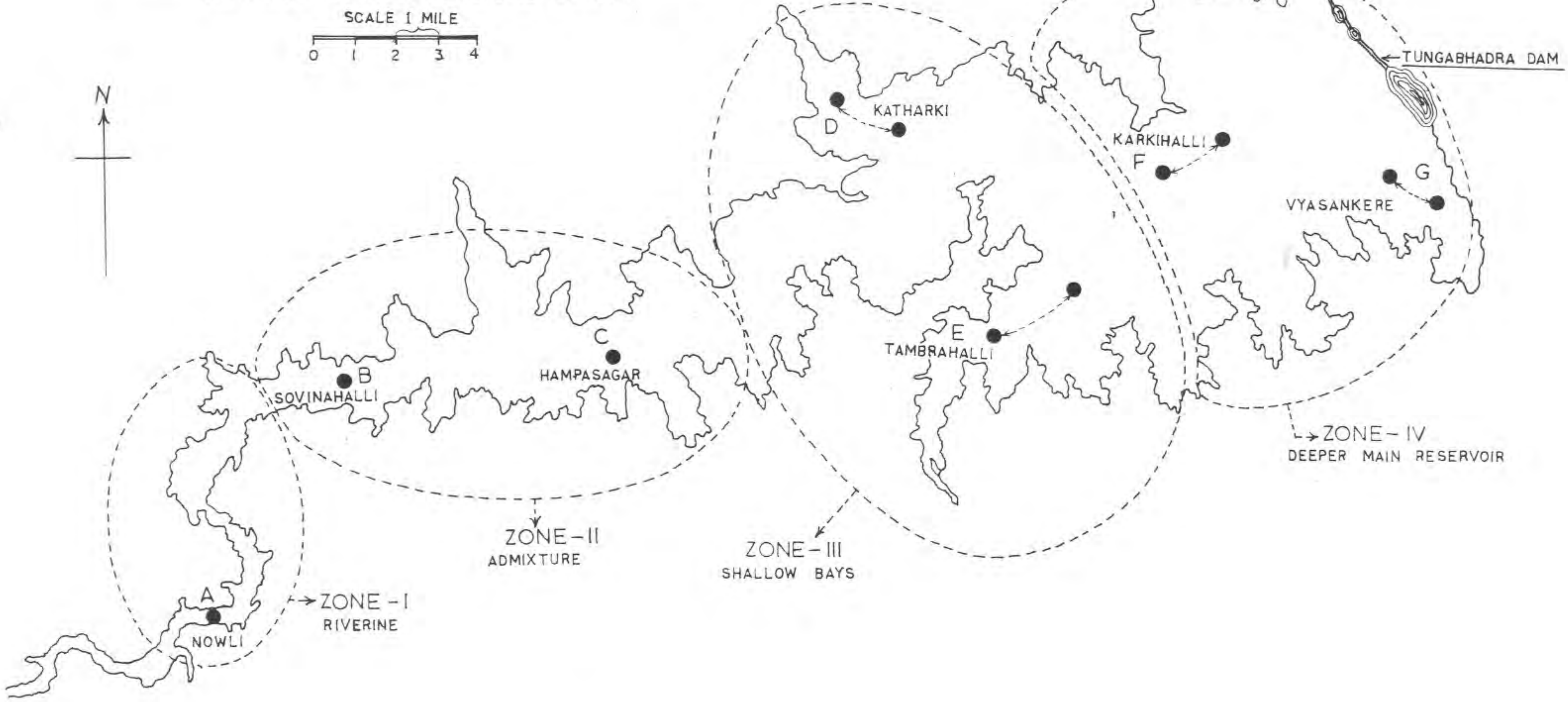
Experimental fishing was undertaken by gill nets of various mesh sizes, ranging from 30 to 150 mm (bar), in all the zones, but modified bottom fishing was introduced in February 1965 and continued upto March 1966. The species composition, lengths, girths and weights of all fish caught were recorded and effectiveness of each type of net at various depths, zones and seasons indicated.

Studies were made by special observations on breeding, recruitment, migration, colonisation of the juvenile fish, and also on the 'weed' and 'trash' fishes. During monsoon floods of 1963, 1964 and 1965, recruitment studies based on egg and larval incursion into the reservoir through

SKETCH MAP – 2

TUNGABHADRA RESERVOIR

MAP SHOWING HYDRO BIOLOGICAL COLLECTION CENTRES AND BIOLOGICAL ZONES



the main river were undertaken, spawn collection nets (shooting nets) being employed at Hesrur and Mudalighatti centres. Regular searches for young, forage and major forms of fishes, were conducted every fortnight, which has given valuable correlated data on composition, recruitment, growth and localised breeding.

ACKNOWLEDGEMENTS AND PERSONNEL

The Tungabhadra Board's authorities provided to the Lacustrine Unit the essential laboratory space and a few quarters during the period of study, evincing interest in the programme of studies. Dr. B.S. Bhimachar, the then Director of the Institute, assigned charge of the Unit to Dr. A. David, Senior Research Officer, in 1963, and gave necessary guidance and encouragement. The late Shri V.V. Kalyani, former Director of Fisheries, Mysore State, and Shri G.V.S. Mani, former Director of Fisheries, Andhra Pradesh, extended their help and encouragement from time to time to the Unit as members of the Fisheries Advisory Committee of the Tungabhadra Board.

Shri P. Ray, Assistant Research Officer (Chemistry), was responsible for the physico-chemical studies, field programmes and correlative limnological interpretations. Shri B.V. Govind, Senior Research Assistant, was responsible for the qualitative and quantitative analyses of plankton and littoral and bottom biota. Shri R.K. Banerjee and Shri S. Lakshmiraghavan, Research Assistants (Chemistry), assisted in soil and water analyses as well as diurnal and basic productivity studies.

Shri K.V. Rajagopal, Research Assistant (Zoology), undertook studies relating to the fisheries biology and fishing experiments under Dr. David's guidance.

Shri K. Gopinathan and Shri P.M. Abdul Kadir, Junior Survey Assistants, were responsible for collection and processing

of data on fish landings, composition, size-weight variations and fishing experiments under the direction of Dr. David. Shri K. Gopinathan drew all the diagrams and charts incorporated in the report. Dr. V.G. Jhingran, Director, Central Inland Fisheries Research Institute, kindly scrutinised the report, suggesting great improvements and arranged its publication as a bulletin of the Institute.

PART I.

LIMNOLOGY

PHYSICO-CHEMICAL CONDITIONS

Seven regular centres (Sketch map 2) were selected for comprehensive observations on the reservoir. These centres were further grouped into four distinct zones indicated below :

Zone No.	Centres	Nature of zone	Approx. distance from Dam site (km)	Approx. distance between centres (km)	Approx. area sq. miles	Approx. area ha	% of water area in the reservoir at 1630 ft (m.s.l)
Zone I	Nowli/Mudalighatti. Centre - A	Riverine Zone	102	Nowli-Mudalighatti-8	12.4	3206	8.5
Zone II	Sovinahalli Centre - B	Transition or Admixture Zone	86	Mudalighatti-Sovinahalli-8.	27.6	7136	18.9
	Hampasagar Centre - C		70	Sovinahalli-Hampasagar-16.			
Zone III	Katharki-Centre - D	Shallow Zone (representing bays)	56	Hampasagar-Katharki-20	33.5	8662	22.8
	Tambrahalli Centre - E		54	Hampasagar-Tambrahalli-26.			
Zone IV	Karkihalli Centre - F	Deeper Zone (representing main reservoir)	16	Tambrahalli-Karkihalli-16	72.5	19746	49.8
	Vyasankere Centre - G		8	Karkihalli-Vyasankere-16			

When the water level reaches the 1590 ft mark, Zones I and II refer only to the main river stream and Zone III disappears completely, with Zone IV alone occupying about 90% of the attenuated reservoir area.

Soil and Sediments

About 75-80% of the reservoir's submerged area is occupied by black and the rest by red soil; bottom sediments indicated mostly dark-coloured but sometimes reddish or yellowish-brown deposits. As the reservoir bed is now covered by silt brought by the river, the original soil characters are replaced by the deposited nature of the silt, which is mainly clayey. Base status of the clayey black soil is characterised by a high proportion of calcium and magnesium, poor in phosphorus. Since turbidity is never high in the reservoir, annual silt precipitation from suspended particles is moderately high, the rate being 41,050 acre ft per year. This has reduced the capacity of the reservoir by 13.5% from the original 30,43,100 to 26,32,600 acre feet in the course of the last ten years. The depth of bottom ooze or soft silt varies between one to three feet (30-90 cm) all over the reservoir except in the deep control portion of the reservoir (Sketch map 3) between Tambrahalli and Katharki Bay mouths, where it varies from 4 to 12 ft (120-360 cm).

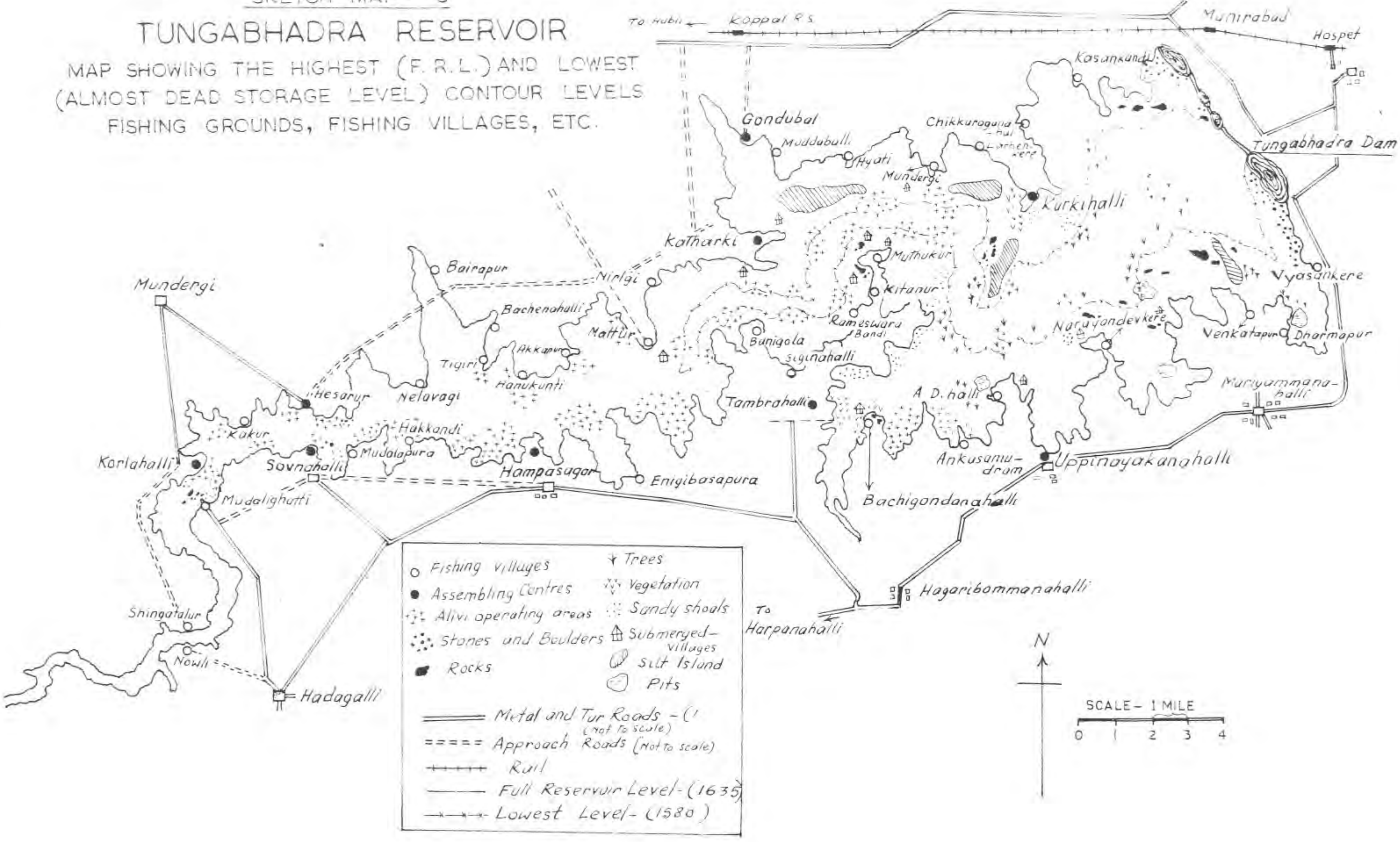
Riverine and Transition (Admixture) Zones :
(Zone I & II)

Silt precipitation in the upper riverine areas, Nowli and Mudalighatti centres and Sovinahalli-Hampasagar stretch, is comparatively less, obviously due to the highly variable currents and wind action on margins. Deposition of both gravel and pebbles with fine suspensoids occurs in the Admixture Zone, where the current is neutralised by the backwash from the reservoir. Cemented boulders and silt are found within this stretch of about 30 km. Soil-silt deposits here are mostly brown, moderately rich in calcium (2000-6000 lb/acre), magnesium (Nil-1000 lb/acre) and soluble salts (specific conductivity 36-255 x 10^{-6} mhos), the total organic matter being 8.6-23.5%. This sedimental structure provides a

SKETCH MAP — 3

TUNGABHADRA RESERVOIR

MAP SHOWING THE HIGHEST (F. R. L.) AND LOWEST (ALMOST DEAD STORAGE LEVEL) CONTOUR LEVELS FISHING GROUNDS, FISHING VILLAGES, ETC.



suitable medium for both molluscs and burrowing aquatic insects. Exposure of sand and original soil at intervals by a flushing action of the current and removal of top layers of silt and colloidal particles with the gradual lowering of water level can be observed along parts of river bed. During this process, continuous oxygenation of the reducible organic matter in the area until March and thereafter wind and wave turbulences make this environment slightly unfavourable for littoral organisms.

Shallow Bays of the Reservoir :
(Zone III)

Tambrahalli and Katharki are the two major bays representing shallow water wings on the right and left flanks of the reservoir. These two bays cover at the maximum level 22.8% of the reservoir area, but disappear completely as soon as the 1610 ft level is reached exposing the bottom for three to four months during the dry period. Two streams, Chikkahagari and Hirehalla, of which the former one is perennial, drain into Tambrahalli and Katharki bays respectively. These streams transport suspended silt from the adjoining catchment areas. The calcium (4000-6000 lb/acre) and magnesium (500-2000 lb/acre) values in the two bays are higher than the original main river deposits. High pH (8.0-8.5), specific conductivity (82-261 $\times 10^{-6}$ mhos) and organic matter (17%) show the bottom soil to be richer than the first two zones. Active disintegration of bottom sediments is not possible due to wind turbulence in these sheltered bays to the degree possible within the main open reservoir or river stretch. Katarki Bay is richer in organic content (16.2% in Tambrahalli and 18.1% in Katarki), and with the suspension of flow in the Katarki Bay, decomposition of bottom sediments begins earlier (end of January) than in the Tambrahalli Bay. Disintegrating bed in stagnant water conditions provides a good medium for colonisation by aquatic oligochaetes, molluscs and insects. Moderate release of ammonia from the soil indicates that bioactivity is more pronounced in this zone. Onset of wind action and consequent erosion of shoreline to an appreciable degree also limit growth of oligochaete colonies. Ammonia released from decaying organic matter (March-April) is not fully mineralised to calcium nitrate (evidenced by low values of nitrate of only 5 lb/acre) due to disturbed conditions in the water, which readily escapes into the atmosphere after a very small percentage of nitrification in water. High concentration of calcium left unused on the sub-soil surface supports the above conclusions.

Deeper Zone (Zone IV) :

While at place the main reservoir shows silt to a depth ranging from 1.2 to 3.3 m (4 to 12 feet), silt deposits of 0.45 to 0.9 m (1½ to 3 feet) and 0.9 to 1.2 m (3 to 4 feet) are encountered at the mouths of Tambrahalli and Katarki Bays respectively. Excepting the deeper areas of this zone, the precipitous inclines and margins are sand, stone or strewn boulders, and almost no silt or mud is encountered. Due to the heavy wave action, as high as 1.5-1.8 m (5 to 6 feet), the margins exhibit bare boulders, rubble and stones, as silt can be deposited only at greater depths. The lowering of water level further contribute to the rubble margins and accumulation of huge quantities of dead molluscan shells. The soil deposits were rather poor in terms of organic and inorganic salts (specific conductivity, 66-131 $\times 10^{-6}$ mhos). (Table 4)

With the exposure of outer bays, soluble salts derived from the top layer deposits by wind action are transposed into the main reservoir's water medium thus enriching it. In May and early June, the bottom sediments in the shallower areas are exposed and some disintegration is then possible. Thus enrichment of the reservoir water occurs by release of nutrients from the marginal beds of deeper and fast shrinking adjoining shallow bays over a wide area. Though the soil is alkaline (pH 7.8-8.0) in the Deeper Zone, the calcium and magnesium values almost correspond with the other zones. In the absence of stabilisation of water levels and constant wind and wave action, active disintegration of bottom sediments does not take place even though temperature is highly favourable. Except for slight increase in the nitrate values in the water and negligible mineralisation, no significant nutritional ingredients are contributed by the sediments.

Table 4.

Zonewise soil characteristics of the Tungabhadra Reservoir

Zone	pH	Calcium lb/acre	Magnesium lb/acre	Ammonia lb/acre	Organic matter (%)	Specific cond. 10^{-6} mhos. (5:100 soil suspension)
Zone I (Riverine Zone)	7.0-8.0	2000	Nil-500	50	8.6-23.5 (13)	72-104 (83)
Zone II (Admixture Zone)	7.2-8.2	2000-6000	500-1000	50-100	8.6-23.5 (13.5)	35-255 (109)
Zone III (Shallower Zone)	8.0-8.5	4000-6000	500-2000	50-100	6.6-26.2 (17)	82-261 (126)
Zone IV (Deeper Zone)	7.0-8.0	1000-4000	Nil-500	100	7.2-26.7 (17)	66-131 (95)

Values indicated within brackets are the average values

Water conditions : (Table 5)

Physical

Temperature : Water temperature varied between 23.1 and 29.5°C. Lower temperatures were recorded between December and February and June to September in all the zones; while higher values were registered during October and November and also during April and May in the Riverine and Admixture Zones, and April-October/November in the Shallower and Deeper Zones. With the lowering of water level in 1965, the temperatures were as high as 30.3, 30.5 and 31.5°C in the Admixture Zone (May) within the Bays (April), and the DeeperZone (May) respectively. At no time an indication of a

Table 5.

Zonewise Physico-chemical characteristics of the Tungabhadra Reservoir

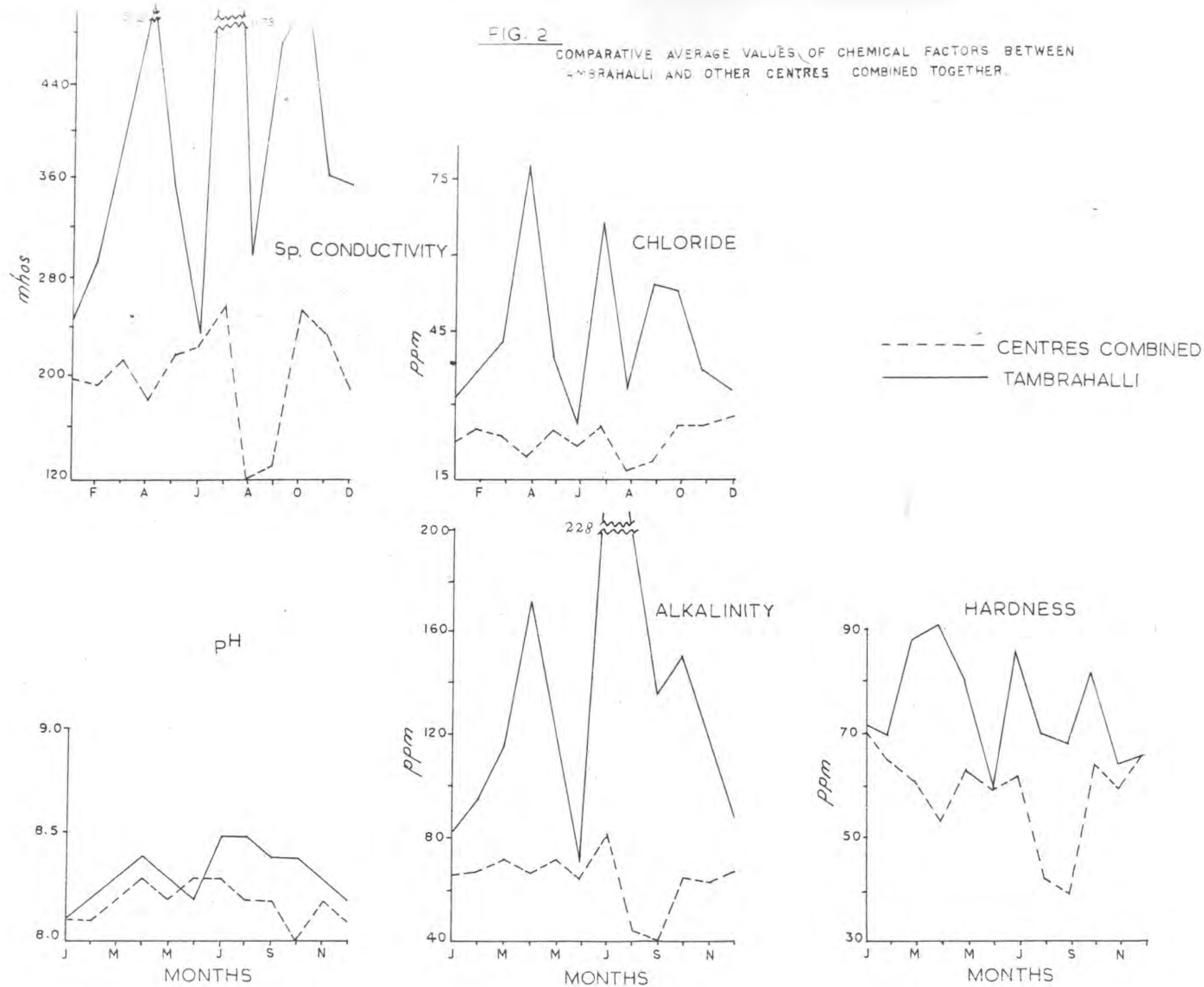
(Range of average values during 1963-64 and 1964-65)

	Riverine Zone		Transition Zone		Shallower Zone		Deeper Zone	
	Range	Average	Range	Average	Range	Average	Range	Average
Temperature in °C	23.2 - 28.3	25.4	23.5 - 28.1	25.5	23.8 - 29.1	26.76	23.1 - 29.5	26.46
Turbidity (mg/l)	100-825	184	100- 700	284.5	100- 400	131.8	100- 246	115.75
pH	8.0 - 8.3	8.13	8.0 - 8.2	8.1	8.1 - 8.5	8.23	7.9 - 8.3	8.125
Dissolved Oxygen (mg/l)	7.0 - 11.1	8.46	6.6 - 9.2	7.38	6.5 - 8.0	6.98	6.4 - 8.1	7.15
Alkalinity (mg/l)	31.0 - 69.0	51.5	31.0 - 88.0	63.3	66.0 - 102.0	81.75	34.0 - 114.0	66.9
Hardness (mg/l)	31.0 - 75.0	54.75	36.0 - 76.0	56.4	43.0 - 74.0	60.08	35.0 - 62.0	53.75
Specific conductivity x 10^{-6} **mhos** at 25°C.	125-213	174	90.0 - 252.0	200.6	225.0 - 459.0	333.4	106.0 - 295.0	199.9
Chloride (mg/l)	12.5 - 24.7	19.7	11.9 - 27.2	22.76	25.1 - 42.1	32.1	12.6 - 28.2	22.26
Nitrate -N (mg/l)	0.14 - 0.33	0.230	0.20- 0.74	0.306	0.11 - 1.52	0.375	0.14- 0.3	0.225
Phosphorus (mg/l) *	Tr - 3.1	0.300	Tr - 3.3	0.390	Tr - 2.8	0.242	Tr - 0.8	0.066
Silicate (mg/l)	6.9 - 15.5	10.66	8.6 - 22.2	11.68	8.2 - 20.1	13.28	8.1 - 20.5	11.45
Iron (mg/l)	0.12 - 0.92	0.398	0.27- 1.32	0.711	0.16 - 0.86	0.465	0.24- 0.91	0.53)

* Tr = Value of 0.03 and less are considered as traces.

FIG. 2

COMPARATIVE AVERAGE VALUES OF CHEMICAL FACTORS BETWEEN AMBRAHALLI AND OTHER CENTRES COMBINED TOGETHER.



thermocline was noted even in the deepest zone of 25 m (82 ft), the temperature difference being 1°C generally and 1.5°C on a few occasions only. A difference of about 0.5°C only was noted between the surface and bottom layers in Zones I & III. 10,500 cusecs of water being drawn into the power-cum-irrigational canals at 1550 and 1560 ft. m.s.l. appears to ensure a bottom current all the year round helping to maintain some uniformity of temperatures between the surface and bottom waters, and intermixing of salts and nutrients.

Turbidity : Clarity of water is (Fig.1) remarkably high in the reservoir. Studies have indicated that heavier particles generally contribute to the turbid state rather than colloidal silt suspensoids, which is substantiated by the fact that the water becomes transparent as early as September with the cessation of rains and floods. Further, high trubidity is not found in the Deeper Zone, there being an almost precipitous fall in the turbidity values from Zone I to Zone IV.

Turbulences due to wind and wave action during the summer months (March and April) are responsible for the turbidity (100 to 200 ppm) in the marginal areas up to a distance of 25 to 50 meters from the shore in the Deeper Zone.

Chemical

pH : The range in variation in pH (Fig.1) was between 8.0 and 8.3 except on some rare occasions when values of as low as 7.9 or as high as 8.5 were recorded. The lowest values were recorded during post-flood periods (September to December), while the highest in summer months (March to May/June).

Dissolved Oxygen : D.O. generally ranged between 6 and 9 ppm (mg/litre). The Riverine and Admixture Zones indicated at times values higher than 9 ppm (i.e. slightly more than 100% saturation). Concentration of D.O. at various zonal centres (80-90% saturation) indicates that neither organic disintegration of bottom sediments was significant nor the water contained sufficient quantities of reducible organic substances. There was little difference in the concentration of dissolved oxygen between the surface and bottom layers of water in all the centres.

The diurnal variations of dissolved oxygen during January to March (the active period of metabolism of phyto-plankton) at various centres and depths indicate that fluctuation in the concentration of dissolved oxygen in general was quite low. Deeper Zone showed high ranges during January and February (January - 3.07 ppm, February - 3.06 ppm) at 8 meter depth, while the Shallower and Admixture Zones indicate lower ranges during March and February (Shallower Zone - 2.08 ppm, Admixture Zone 2.01 ppm) in surface waters only (Table 5 A). Productivity experiments conducted (carbon assimilation as mg/M^3/day) at various centres and depths during summer by Light and Dark Bottle method, indicate the Shallower Zone to be more productive than the Deeper Zone. March and April, however, were the most productive months.

Alkalinity and Hardness : The water was fairly alkaline in character due to carbonates and bicarbonates of calcium and magnesium, and never showed non-carbonate hardness. Alkalinity ranged between 56 and 70 ppm with slight fall during monsoon at all centres except in Tambrahalli where it was 71-228 ppm. Hardness values also indicated similar trends in concentrations. For short periods carbonates were present in very low values i.e. once during post-monsoon (highest flood) and again during the extreme summer months. Alkalinity in water would have increased considerably in summer by dissolution of huge numbers of small calcareous shells of dead gastropods and bivalves, but this was not possible because release of carbon-di-oxide or hydrogen-ion by disintegration of bottom deposits containing these shells was not significant. The high alkalinity value at Tambrahalli centre was mainly due to the washings of limestone deposits in the catchment by the Chikkhagari river(Fig.1).

Specific conductivity : Soluble salts in any sheet of water which has to produce a bio-mass, are of great importance, and in the Tungabhadra reservoir, fairly high values were observed in all shallower regions. Specific conductivity ranging between 240-359 x10^{-6} mhos in 1964 rose to 493 x 10^{-6} mhos in 1965. Low values were observed in the Deeper Zone (Zone IV), while in the Admixture Zone (Zone II) the values ranged mostly between 159-235 x 10^{-6}. The value in the Riverine Zone was, however, the lowest, being 176-180 x 10^{-6} mhos in 1964 and 244 x 10^{-6} mhos in 1965. Due to the abnormally low flood conditions and limited surface run-offs from the catchments specific

Table 5 A.

Zonewise diurnal variation of dissolved oxygen during January - March

Zone / Month	Depth	8 am	12 am	4 pm	8 pm	12 pm	4 am	Range of Variation
Zone II (Admixture Zone)								
February	Surface	6.99	5.99	6.76	8.00	7.59	7.31	5.99 - 8.00 = 2.01
	Bottom	5.59	5.80	5.91	7.36	6.80	6.61	5.59 - 7.36 = 1.77
March	Surface	6.02	5.67	6.40	5.66	5.44	5.78	5.44 - 6.40 = 0.96
	Bottom	5.80	6.03	5.90	6.38	5.68	5.89	5.38 - 6.38 = 1.0
Zone III (Shallower Zone)								
January	Surface	7.91	8.86	8.72	7.89	7.16	7.60	7.16 - 8.86 = 1.70
	Bottom	7.59	6.96	7.76	7.65	7.70	7.45	6.96 - 7.76 = 0.80
February	Surface	6.89	6.91	7.31	7.97	7.44	6.97	6.89 - 7.97 = 1.08
	Bottom	6.49	5.55	5.65	6.46	6.68	6.14	5.55 - 6.68 = 1.13
March	Surface	5.99	6.65	7.26	6.72	6.10	5.18	5.18 - 7.26 = 2.08
	Bottom	5.91	6.07	6.33	5.93	4.92	4.78	4.78 - 6.33 = 1.55
Zone IV (Deeper Zone)								
January	Surface	9.526	9.408	9.408	9.650	9.408	8.624	8.624- 9.659 = 1.035
	4 m.	9.894	9.800	10.584	9.604	9.212	8.820	8.820- 10.584 = 1.764
	8 m.	9.408	9.800	10.584	9.133	8.624	7.510	7.510- 10.584 = 3.074
	12 m.	9.648	9.918	9.918	8.624	7.330	7.510	7.510- 9.918 = 2.408
	16 m. (Bottom)	9.468	9.408	9.408	8.624	7.408	7.076	7.076- 9.408 = 2.332
February	Surface	7.64, 8.5	7.258	6.494	7.243, 8.5	5.677	6.112	5.677- 7.640 = 1.963
	4 m.	7.243	7.015	6.876	7.411	6.112	6.379	6.112- 7.411 = 1.299
	8 m.	7.258	4.584	7.029	7.64	6.356	6.876	4.584- 7.64 = 3.056
	12 m.	7.166	7.090	6.631	7.876	5.974	6.325	5.974- 7.876 = 1.902
	16 m.(B)	7.044, 8.5	8.404	7.143	7.402, 8.3	5.837	5.837	5.837- 8.404 = 2.567
March	Surface	6.336, 8.4	6.094	4.792, 8.3	6.076, 8.3	x	x	4.792- 6.336 = 1.544
	4 m.	5.184	5.76	4.608	5.616	x	x	4.608- 5.760 = 1.152
	8 m.	6.497	5.27	5.184	6.134	x	x	5.184- 6.497 = 1.313
	12 m. (B)	5.184, 8.3	5.213	4.973, 8.3	6.059	x	x	4.973- 6.059 = 1.086

x = Samples could not be collected.

conductivity decreased (82-151 x 10^{-6} mhos) at all the centres, while with floods Tambrahalli Bay alone showed an increased value of as high as 1173 x 10^{-6} mhos (1964), recorded during the studies once. With the lowering water level and increased wind velocity, concentration of salts gradually rose higher, specific conductivity showing an increase simultaneously.

Chloride : Chloride values varied generally between 16 and 25 ppm except in the Shallower Zone where values as high as 25 to 67 ppm were noted. These high values were recorded in the Tambrahalli Bay where the sewage and refuse of Hagaribommanahalli town are received through the Chikkahagari river. Except for the Tambrahalli Bay region which is subjected to some sewage enrichment directly no other region of the reservoir is subject to organic pollution(Fig.1).

Nitrate : Nitrate values, in general, were between 0.2 and 0.5 ppm, a fairly high range irrespective of summer or flood conditions, the Shallower Zone being comparatively richer (0.3-0.4 ppm). During rainy months, the nitrates are supplied through flood washings while in summer low levels, the supply is ensured by bottom sediments. With a rise in temperature from February onwards, though decomposition of bottom sediments starts in the shallower regions the values do not rise too high due to wind turbulences and a continuous drawn down.

Phosphate : Phosphate values were mostly in traces (0.02 to 0.03 ppm) or absent. On a few occasions sudden but unusual high values (0.1 to 3.3 ppm) were recorded especially during unstable water conditions in February, March and August in the Riverine Zone (Zone I), in February and March in the Admixture Zone (II), in February in the Shallower Zone and in January in the Deeper Zone. It has not been possible to account for such high phosphate values. These high values did not also apparently influence plankton densities. Rain washings from the rich agricultural catchment and the surrounding peripheral lands which are subjected to super-phosphate manuring constitute the source of supply of phosphorus. During floods, however, little phosphorus was recorded in the river water, and even in bottom sediments and soils, phosphorus was not appreciable. The available phosphorus indicated very low values and probably phosphates were not available to the overlying water in the absence of suitable pH. In presence of only traces of soluble phosphorus, productivity of biomass appears checked, although other factors are favourable. Any correlation between phosphorus values and planktonwas, however, not proved in the present studies.

Silicate : Dissolved silicates varied between 9 and 16 ppm; with onset of floods, slightly depressed values were noted, which gradually improved in the subsequent months. High concentrations were maintained throughout the reservoir in all the zones.

Iron : Iron showed high concentrations (0.1 to 2.2 ppm) which seems to be directly related to local flood conditions and summer turbulences. Washings from an ore-rich catchment in the neighbourhood of the reservoir (right flank) and marginal iron salt deposits leached generously increasing the iron content in the reservoir. All centres exhibited uniformly high concentrations. In the absence of any intensive disintegration of bottom deposits and participation of such salts in chemical reactions, no adverse effects of iron were noted.

Individually, Tambrahalli indicated highest values in most of the chemical constituents (Fig.2) while amongst zones the Shallower Zone (Zone III) was found to be richer than the other zones (Fig.1). Nutrient status in the Tungabhadra reservoir however shows a tendency to increase from 1959 to 1965.

MACROPHYTIC VEGETATION

The aquatic macrovegetation of the Tungabhadra reservoir comprised at least 16-17 genera. Zone IV was the poorest being almost an aquatic desert (4 genera), the other zones in order of abundance of vegetation being Zone I (5 genera), Zone II (11 genera) and Zone III (12 genera), the last being the richest (Table 6).

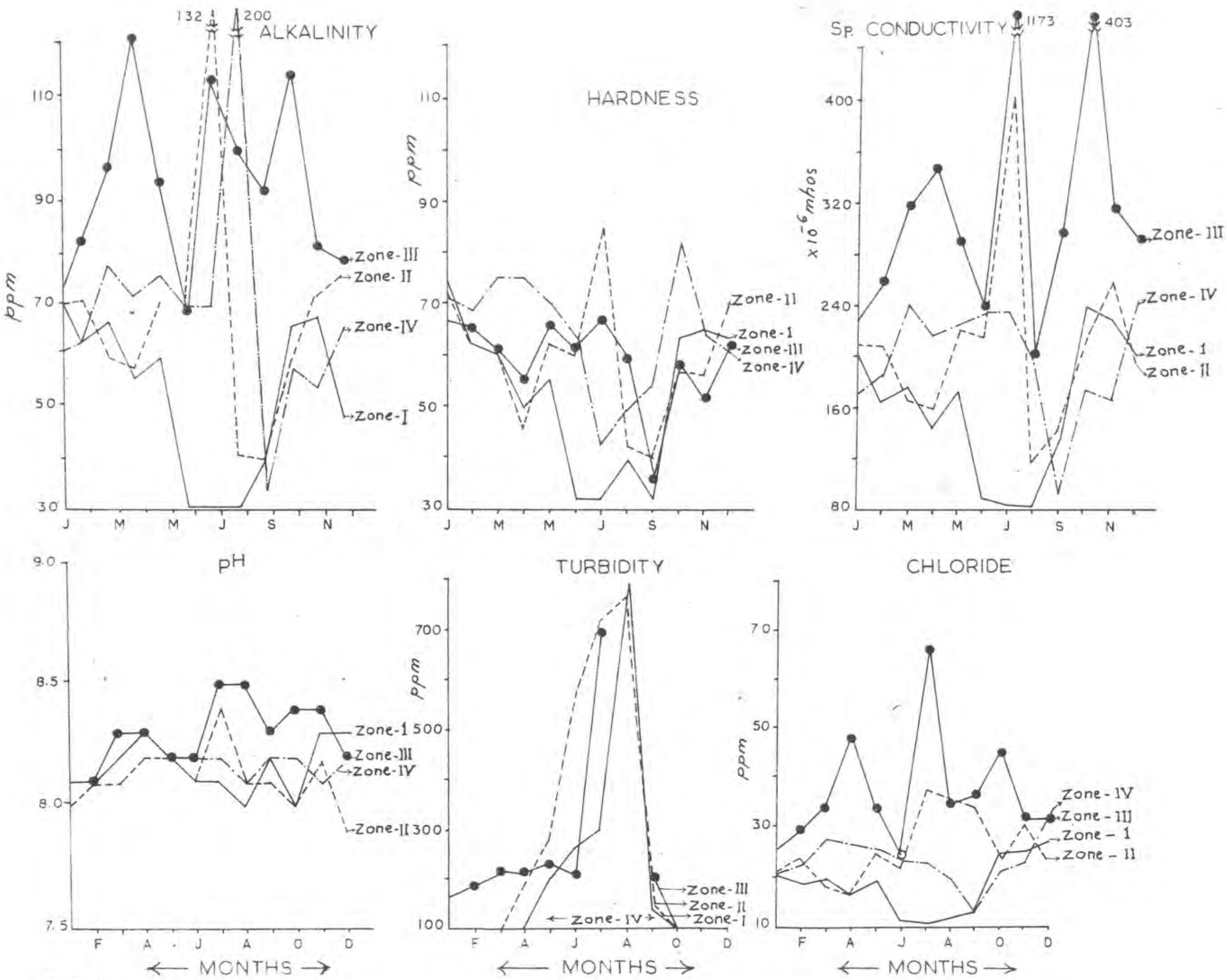


FIG. 1. RELATIVE VALUES OF SOME CHEMICAL CONSTITUENTS ZONEWISE BASED ON TWO YEARS DATA

Table 6.

Macrophytic flora of the Tungabhadra Reservoir

Genera/species — Zones / Centres	I A	II B	II C	III D	III E	IV F	IV G	Remarks
1. *Hydrocera*	-	-	-	x	-	-	-	Floating stem
2. *Polygonum barbatum*	x	-	-	-	x	-	-	Amphibious floating
3. *Ceratophyllum demersum* (?) Retz.	-	-	x	x	x	-	-	Submerged and floating
4. *Hydrocaritacea*	-	x	x	-	-	-	-	Submerged
5. *Hydrilla* spp.	-	x	-	-	x	x	-	"
6. *Otellia allismoides* Pers. Syn.	-	x	-	-	x	-	-	Rooted and submerged
7. *Vallisneria*	x	x	x	x	x	-	-	"
8. *Aponogeton crispum*(?) Thumb	x	x	x	-	-	-	-	Rooted marginal
9. *Potamogeton* spp.	-	-	-	x	x	-	-	"
10. *Nais minor* Allioni	-	-	-	-	x	x	-	Submerged and floating
11. *Cyperus exaltatus*(?) Retz.	x	x	x	-	x	-	-	Rooted and floating
12. *Graminae*	x	x	x	x	x	x	-	Creeping and floating
13. *Marsilea quadrifoliata* Linn.	-	x	-	-	x	-	-	Amphibious submerged
14. *Chara* spp.	-	x	-	x	-	x	-	Rooted marginal
15. *Cyperus* spp.(a)	-	x	x	-	x	-	-	Creeping and floating
16. *Cyperus* spp.(b)	-	x	-	-	-	-	-	"
17. Unidentified	-	-	-	-	x	-	-	Submerged and floating
	5	11	7	6	12	4	-	

x = Present. - = Not recorded.

Zone I (Centre A)

The riverine condition of this zone with its abrupt sandy and clayey margins could harbour only scanty vegetation. The sparse terrestrial vegetation included the leguminous shrubs present on the sandy and silty river banks while the slopes nurtured a few marshy, rooted, amphibious *Polygonum barbatum* and the marginal aquatic *Aponogeton crispum*, as well as submerged *Vallisneria* in patches. The creeping herbs like Graminae and the rooted floating *Cyperus exaltatus* were also recorded.

Zone II (Centres B and C)

Vegetation of this silt ladden black soil zone with its gradual slopes and shallow inundable areas was dense during the post-monsoon (south west) period than in the summer months when but for some terrestrial xerophytic spiny shrubs on the adjoining land, the aquatic vegetation was almost restricted to some hardy varieties of *Cyperus*. The marginal areas of this zone with a loose sand and silty bed, up to a depth of one meter or so during summer months, indicated thick algal mats comprising mostly sessile colonies of microvegetation like blue-green algae. Even during the low water periods, the lagoon condition of this zone supported *Aponogeton crispum* (?) and *Marsilia quadrifoliata*. In the post-monsoon period, the rooted aquatic species like *Otellia alismoides*, *Cyperus* spp., *Vallisneria* spp., *Chara* and *Hydrilla* spp. and submerged, floating, *Ceratophyllum demersum*, were common, forming the 'Pleuston'.

Zone III (Centres D and E)

This zone represents a rather lentic environment than a fluviatile condition and the stagnant oozy, humic soil bears the maximum number of macro and micro-vegetation among all the four zones of the reservoir. Of the two centres in this zone, centre E was richer in possessing 12 genera while centre D had 6 genera only. In addition to those indicated in the list and mentioned earlier, *Potamogeton* spp. was recorded in this zone. These and other rooted vegetation of the margins harbour a rich littoral fauna. In general during the summer months when Tambrahalli Bay (Centre E) becomes almost a swamp for a short period, the vegetation comprises Marsilia quadrifoliata and Cyperus spp. After the monsoon, this centre shows a green lush vegetation composed of terrestrial herbs and shrubs. Aquatic vegetation to a depth of one to two meters in the littoral zone that could be termed as 'Mesolimniac' (rooted and submerged), is also noticed. Forms like Potamogeton spp., Vallisneria spp., Cyperus exaltatus and Cyperus spp., Polygonum barbatum, Graminae, and 'spilimnionic' (submerged floating) Naias minor, Ceratophyllum demersum and Hydrilla spp., were recorded. The above are characteristics of the lentic environment existing in the bay. Otellia alismoides, Hydrilla and others with their subterranean shoots, harbour a rich variety of littoral fauna like prawns, aquatic insects (may-fly and dragonfly nymphs) which attract fishes to colonise the bay accounting for the richer fish life. The richness of the zone is further aided by cyclic changes brought about by a decomposition of the above vegetation which acts as a manure. This manurial action is enhanced by the Hagari river. Centre E of this zone was relatively richer with regard to vegetation. The vegetation also included Hydrocera, usually present in lentic environments.

Zone IV (Centres F and G)

Of the two centres, only centre F of this zone, with its semi-rocky and semi-silty conditions could support scanty patches of vegetation like Chara spp., Hydrilla spp., Naias minor and Graminae. Centre G being nearest the Dam, and abrupt in its depth with a rocky substratum, represented an aquatic desert.

LITTORAL BIOTA

The littoral biota as a whole was dominated by crustaceans (prawns), insects, gastropods, small fishes, bivalves, tadpoles and aquatic oligochaetes in order of abundance by numbers (Fig.3). Prawns were 35.0-40.0 % by numbers and 16.6-22.8% by weight, insects 28.8-36.7% by numbers and 15.2-22.6% by weight. Other groups are as shown in Fig.4 for each zone for two years.

The general pattern of seasonal variation in abundance was an insect dominance during September-October, followed by prawns in February and March, and by molluscs in April and May. The variation in numbers and weights of all groups in gms/m^2 are shown in Table 7.

Among various zones of the reservoir, the distribution trends varied highly. The Shallower Zone III (Centres E and D) was found to be the richest, followed by Zones II, IV and I in order of abundance of numbers. Zones I and II were dominated by insects, Zone III by prawns and Zone IV by molluscs. Fishes were in a higher concentration in Zone III.

Prawns

Prawns were the most dominant group (43.0% by number and 34.4% by weight) in the whole reservoir, being contributed in main by Zone III. Their annual averages ranged from 0.04 to 29.34 units/sq m from Zone I to Zone III. There was a decrease in prawn population in Zones III and IV and an increase in Zone II from first to the second year. The average numbers/sq m ranged between 2 to 36 units, the maximum being 166 units in March. The dominant form was Leander spp. which was also common in the drainage.

Insects

The insect group comprised aquatic insects and the nymphal and larval stages of terrestrial forms.* Insects were most dominant in Zone II forming 68.7% by number and 45.1% by weight in the first year. There was a decrease in number of insect groups from Zone II to III. While they decreased in numbers between the two years in Zones I and II, they recorded an increase in Zones III and IV. Chironomids were higher in Zone I and II, corixids in Zone III and may-fly nymphs in Zone IV. While chironomids and may-fly nymphs were found in all the

* Including Chironomid larvae; the expressed results do not represent a true picture of the group as such.

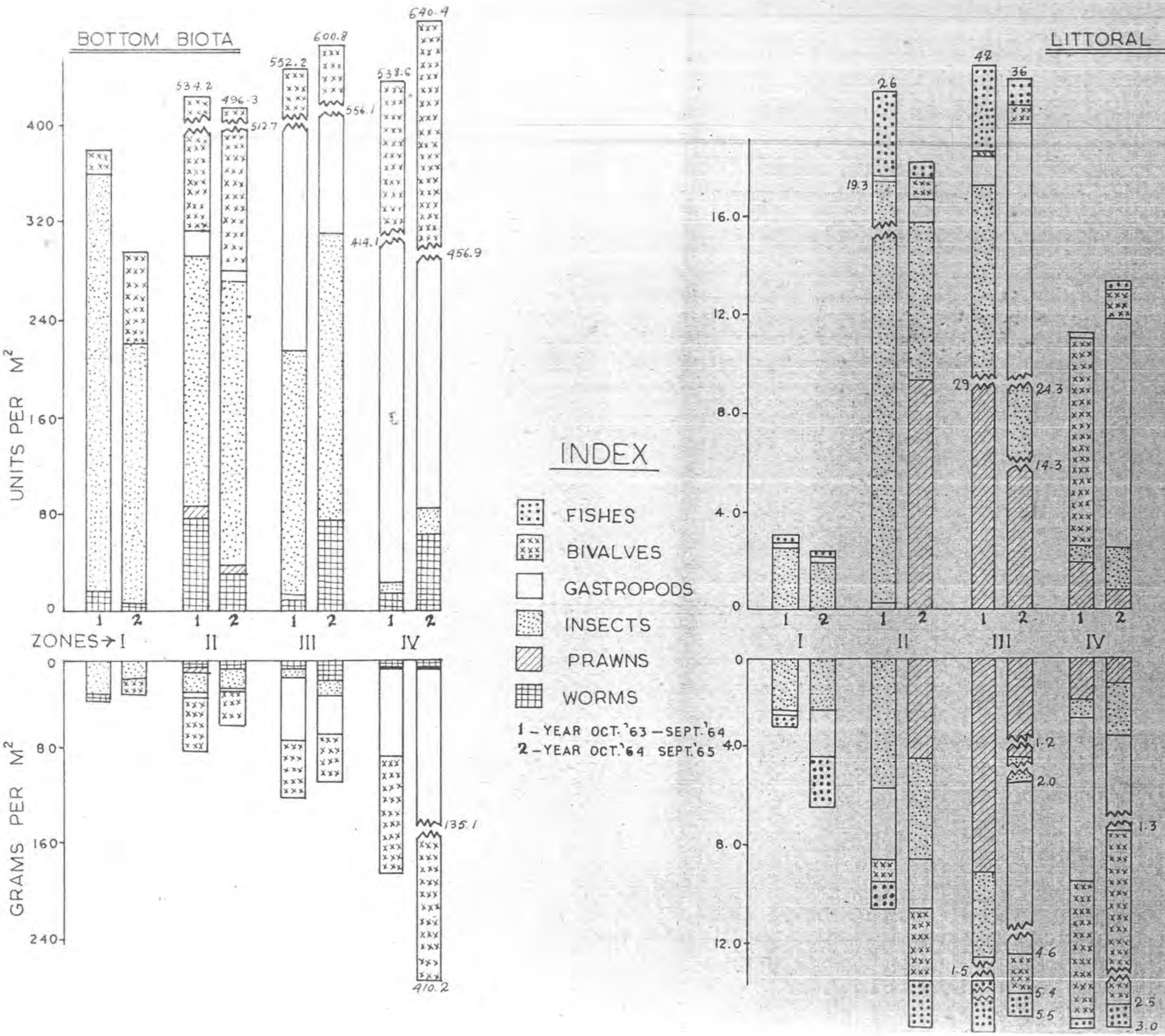


FIG. 3 ANNUAL AVERAGES OF BOTTOM AND LITTORAL BIOTA NO. & GM/M² AT VARIOUS ZONES.

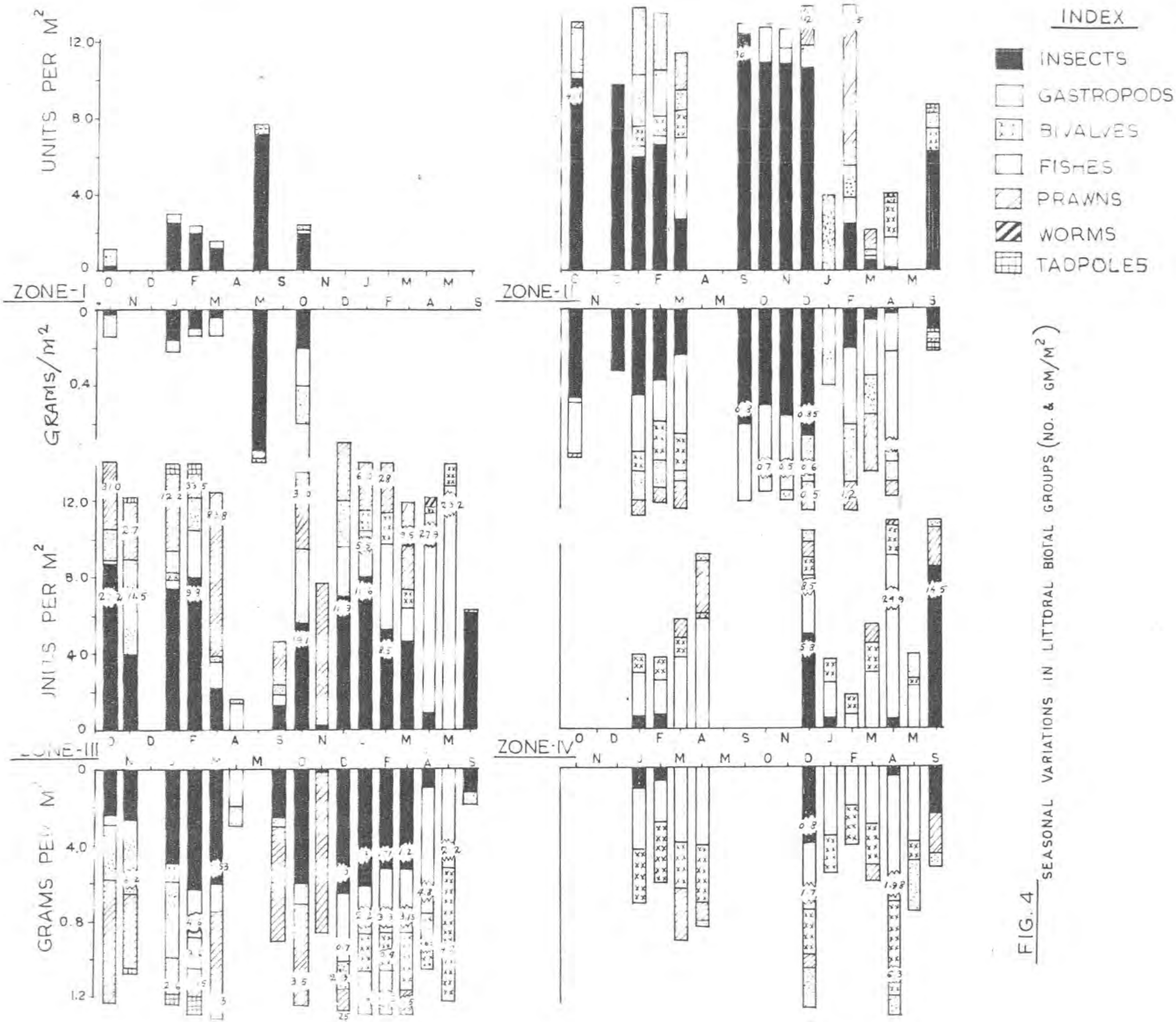


FIG. 4 SEASONAL VARIATIONS IN LITTORAL BIOTAL GROUPS (NO. & GM/M^2)

Table 7.

Littoral Biota of Tungabhadra Reservoir

(Numbers per square meter)

Zones / Centre(s)		Oct. '63 – Oct. '64	Nov. '63 – Nov. '64	Dec. '63 – Dec. '64	Jan. '64 – Jan. '65	Feb. '64 – Feb. '65	Mar. '64 – Mar. '65	Apr. '64 – Apr. '65	May '64 – May '65	Jun. '64 – Jun. '65	Jul. '64 – Jul. '65	Aug. '64 – Aug. '65	Sep. '64 – Sep. '65
I Centre A (Nowli)	1.	1 (0.14)	N	N	3 (0.22)	2 (0.14)	2 (0.14)	N	8 (0.80)	Nc	Nc	Nc	N
	2.	2 (0.60)											
II Centres B & C (Sovinahalli and Hampasagar)	1.	52 (0.64)	N	10 (0.32)	14 (1.03)	14 (1.02)	6 (1.14)	N	Nc	Nc	Nc	Nc	30 (1.40)
	2.	13 (1.20)	12 (1.10)	24 (2.0)	4 (0.40)	32 (2.10)	2 (0.85)	5 (1.65)	"	"	"	"	9 (0.22)
III Centres D & E (Tambrahalli and Katarki)	1.	5 (1.21)	29 (1.30)	N	22 (1.31)	48 (2.70)	88 (3.37)	2 (0.30)	Nc	Nc	Nc	Nc	5 (0.60)
	2.	54 (4.20)	8 (0.86)	20 (2.25)	24 (4.25)	42 (6.26)	18 (5.25)	15 (2.79)	25 (6.4)	"	"	"	7 (0.18)
IV Centres F & G (Karkihalli and Vyasankere)	1.	N	N	N	4 (0.70)	4 (0.58)	6 (0.85)	9 (0.91)	Nc	Nc	Nc	Nc	Nc
	2.	"	"	17 (3.00)	4 (0.55)	2 (0.40)	6 (0.60)	27 (8.42)	4 (0.75)	"	"	"	17 (0.52)
Average for the entire reservoir	1.	35.3 (0.66)	29 (1.30)	10 (0.32)	11 (0.81)	17 (1.11)	25.5 (1.37)	5.5 (0.61)	8 (0.80)	Nc	Nc	Nc	17.5 (1.0)
	2.	23 (2.00)	10 (0.98)	20.3 (2.42)	11 (1.73)	25.3 (2.92)	8.7 (2.23)	15.7 (4.29)	14.5 (0.70)	"	"	"	11 (0.31)

Figures in parenthesis represent weight in grams/m^2.

Nc = Not collected.

N = Negligible.

zones, the common forms in Zones I, III and IV were dragon-fly and damsel-fly nymphs and water bugs. In addition to the above, *Ranatra* was present in Zone II, tabanid insects and water spiders in Zone III.

Molluscs

Next to insects, molluscs were the most dominant group among the littoral biota accounting for 14.5-32.7% by number and 1.97-6.63% by weight during the two years. Molluscs were dominant in Zone IV and III. Gastropods dominated among the molluscs. The ranged varied from 2 units in Zone I, 2-8 units in Zone II, 3-10 units in Zone III and 2-16 units in Zone IV, the maximum being 44 units/sq m in Zone IV in April. Gastropods were represented by *Vivipara* spp., *Lymnaea* spp., *Planorbis* spp. and *Gyraulus* spp., in order of their numerical abundance. Bivalves were mainly represented by *Corbicula* and *Unio* spp. There was an increase in the molluscan fauna from 1963-64 to 1964-65.

Fishes

Young fishes which were encountered in the littoral zone formed 3.2-8.5% by number and 5.3.-12.0% by weight in annual averages (Table 7). Fishes were in general common in Zones II and III, Zones IV and I coming next. Species recorded include young *Puntius dobsoni*, *Puntius kolus*, and *Barilius* spp. in Zone I; *Puntius ticto*, *Puntius stigma*, *Macropodus cupanus*, *Ambassis ranga* and *Oxygaster* spp. in Zone II. *P. ticto*, *P. stigma*, *Glossogobius giuris*, *Ompok bimaculatus*, *Rasbora* spp., *Cirrhina reba*, *Gagata itchkea*, *Osteobrama vigorsii*, *Aspidoparia morar* and *Oxygaster* spp in Zone III and *Oxygaster* spp. and *G. giuris* in Zone IV.

In general there was a decline in fish numbers during the second year in all the zones except Zone III which recorded an increase during post-monsoon months.

Tadpoles

These were confined to Zones II and III, being more abundant in the latter. They formed 0.1-0.3% by number and 0.1-0.6% by weight of the annual averages.

Oligochaetes

Aquatic oligochaetes like Tubifex spp. formed only 0.2% by number and 0.1% by weight of the annual averages. They were recorded in Zone III.

The dominance of the different groups in the four zones could be summarised as insect dominance in Zone I and II, prawns in Zone III and molluscs in Zone IV, which is indicative of the ecological niches they have occupied in the four zones. Zone III, with its shallow nature and vegetative cover is capable of sheltering prawns and insects, which in turn support a good juvenile fishery.

The zone-wise distribution of littoral biota in view of the prevailing ecological conditions is given below :

Zone I : Riverine Zone (Centre A)

The flowing condition of water in this zone with a mainly sandy, silty bed and abrupt steep margins to which could be added the prevalent wind action makes this zone highly unsuitable for colonisation by littoral biota, which are consequently low. The few forms which are present include burrowing aquatic insects, may-fly nymphs and riverine Corbicula spp. of bivalves.

Zone II : Admixture Zone (Centres B & C)

The zone, where the backwash of the reservoir nullifies the lotic conditions, is a serpentine lagoon, covering a wide area from July-August to January but getting narrowed and breaking up into isolated creeks thereafter.

The silty soil rich in calcium and magnesium in addition to the vegetation, is capable of supporting a dense population of molluscs and aquatic insects. During summer months, when this zone becomes fluviatile due to draw-down, considerable damage is probably caused to the littoral population. Insect and prawn abundance is low in summer months, the most affected group being the molluscs. However, the only groups which are conspicuous are gastropods and aquatic oligochaetes, which can resist (being sessile) any dislodging caused by the turbulance of wind and wave action as well as marginal currents.

Zone III : Shallower Zone (Centres D & E)

This zone represents a more stabilised high water condition from July-August to January, when there appears an abundance of vegetation especially at Centre E from about September and consequently, a rich littoral fauna. In this period peaks in insect population in both the centres of this zone are observed comprising corixids, chironomids, may-fly nymphs and others. Prawns contribute to the bulk of littoral fauna in this zone (Centre E). During August-January, enrichment of nutrients (Centre E) caused by the inflow of Chikkahagari river results in higher basic productivity than at any other centre. In turn this supports a dense vegetation cum littoral biota offering abundant food for fishes until February. This accounts for the zone being the richest of all the four zones. Also, the Centre E is better protected from wind action by the presence of hillocks unlike Centre D (Katharki), which is rather open. The water remains clear at Centre E than at Centre D into which also a seasonal river called Hirehalla brings some nutrients.

After March, Katharki Bay harboured a greater population of gastropods (66.0% Vivipara and Lymnaea spp.) as compared to 8.8% at Centre F during 1964-65. Molluscs dominated by gastropods were contributed by the Centre D of this zone, insect and oligochaete fauna being relatively poor in summer.

Zone IV : Deeper Zone (Centres F & G)

Centre F has a substrate of sand and silt over a rocky bed unlike Centre G which is almost completely boulder strewn. The ecological features of both the centres were reflected in their relative richness. Centre G was an aquatic desert with almost a total absence of macrovegetation and very little littoral fauna. In general, this zone was dominated by molluscs, both bivalves and gastropods, and a few insects. Littoral area in this zone was characterised by a superabundance of dead molluscan shells, cast off by waves from the deeper regions.

BOTTOM BIOTA

The bottom macrofauna of the Tungabhadra reservoir was high both in number and weight as compared to the littoral fauna, the dominant forms being molluscs (with a predominance of gastropods), insects, oligochaetes and prawns. Molluscs were 57.6-66.0% by number and 85.2-88.8% by weight, followed by insects 33.5-37.3% by number and 6.5-10.4% by weight, oligochaetes 6.1-8.6% by number and 4.0-4.6% by weight and prawns 0.3%-0.6% by number and 0.1-0.5% by weight (Table 8 and Figs. 5a and b).

Of all the four zones, the Shallow Zone was the most productive during the first year, followed by Zones IV, II and I. During the second year, the Deeper Zone was the richest possibly due to the abnormally low water level resulting in maximum numbers of molluscs.*

Molluscs : Molluscs were the most dominant group of bottom fauna accounting for 59.1% by number. They were the most dominant in Zones III and IV but showed a gradual decrease in their abundance from Zone IV to I. Gastropods dominated over bivalves in Zones III and IV, while the bivalves dominated over gastropods in Zone II; Zone I was exclusively represented by riverine bivalves.

Gastropods recorded in order of abundance were <u>Vivipara</u> spp., <u>Gyraulus</u> spp., <u>Lymnaea</u> spp., <u>Planorbis</u> spp. and <u>Pila</u> spp.

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* These high numbers are due to accumulated dead shells entering the counts.

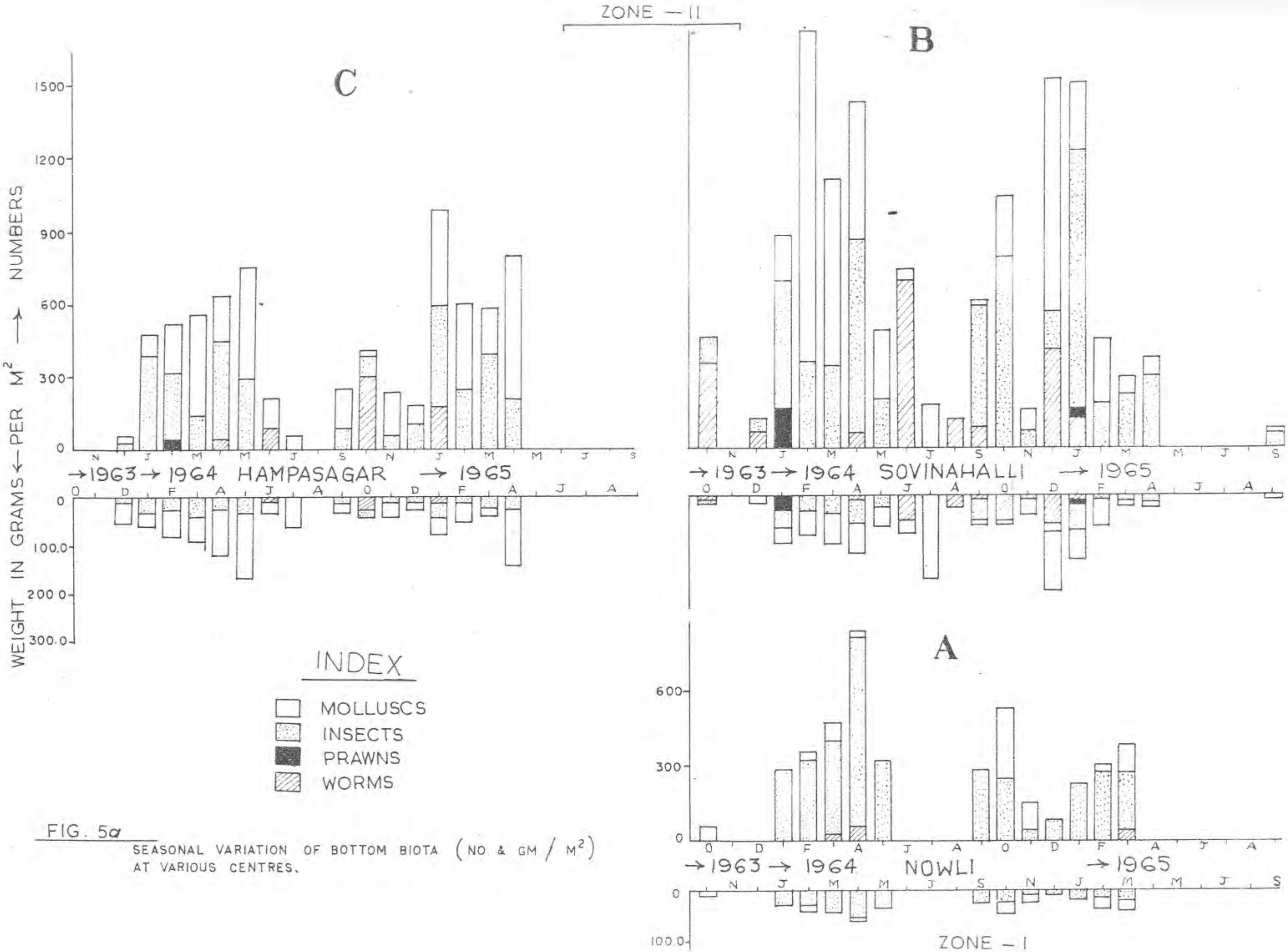


FIG. 5a

SEASONAL VARIATION OF BOTTOM BIOTA (NO & GM / M²) AT VARIOUS CENTRES.

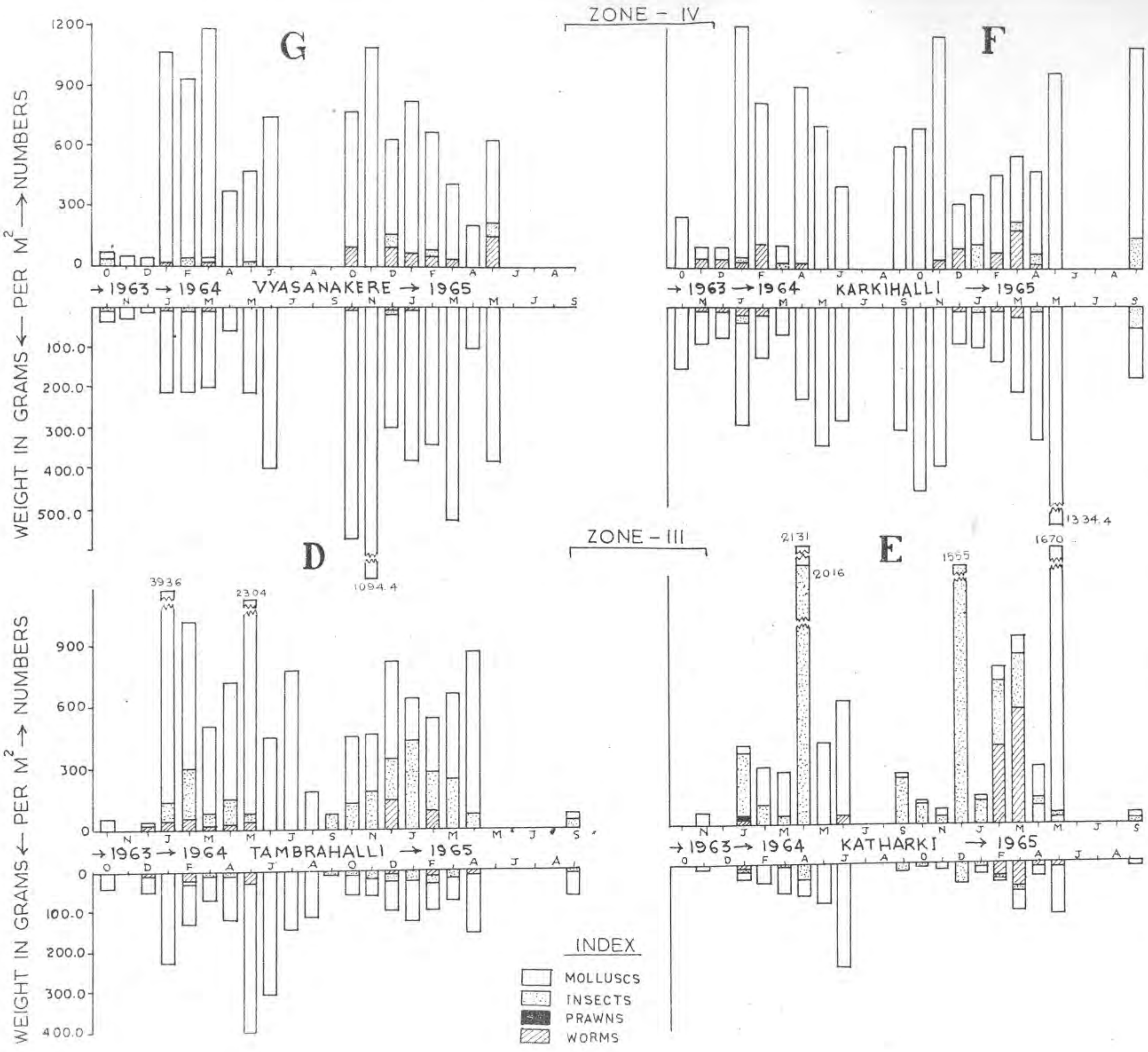


FIG. 5b SEASONAL VARIATION OF BOTTOM BIOTA (NO. & GM / M²) AT VARIOUS CENTRES.

Table 8.

Bottom biota of Tungabhadra reservoir during 1963-65

(Numbers per sqare meter)

Zones		Oct '63 / Oct '64	Nov 63 / Nov 64	Dec 63 / Dec 64	Jan '64 / Jan '65	Feb 64 / Feb 65	Mar 64 / Mar 65	Apr 64 / Apr 65	May 64 / May 65	Jun 64 / Jun 65	Jul 64 / Jul 65	Aug 64 / Aug 65	Sep 64 / Sep 65
Zone I Centre A Nowli	1.	57 (3.8)	N	N	290 (23.0)	365 (37.4)	480 (97.9)	845 (57.6)	326 (28.9)	Nc	Nc	Nc	288 (19.2)
	2.	338 (42.2)	154 (23.0)	77 (5.8)	230 (15.4)	307 (32.6)	384 (38.4)	Nc	Nc	Nc	Nc	Nc	Nc
Zone II Sovinahalli & Hampasagar Centres B & C	1.	221 (5.8)		137 (31.7)	672 (74.9)	1104 (79.7)	826 (87.3)	922 (116.2)	614 (114.2)	470 (51.8)	116 (110.4)	58 (9.6)	423 (41.3)
	2.	711 (48.0)	192 (38.4)	336 (107.6)	1229 (101.4)	519 (56.7)	432 (24.6)	576 (79.7)	10 (1.9)	Nc	Nc	Nc	115 (3.8)
Zone III Centres D & E Tambrahalli and Katarki	1.	29 (19.2)	29 (3.9)	19 (35.0)	2160 (128.6)	663 (77.7)	394 (70.0)	1431 (96.0)	1354 (228.8)	538 (279.84)	394 (70.0)	96 (57.6)	39 (1.5)
	2.	288 (29.8)	279 (31.7)	1200 (70.1)	394 (72.9)	672 (69.2)	807 (93.1)	586 (80.3)	535 (62.8)	Nc	Nc	Nc	58 (38.4)
Zone IV Centres F & G Karkihalli & Vyasankere	1.	164 (93.1)	77 (56.6)	67 (41.3)	1143 (252.5)	883 (162.0)	653 (133.0)	643 (144.0)	595 (278.4)	576 (345.6)	Nc	Nc	307 (153.6)
	2.	739 (568.4)	836 (745.9)	480 (198.9)	1210 (240.0)	576 (241.9)	499 (372.3)	356 (217.9)	816 (330.2)	Nc	Nc	Nc	567 (82.7)
Average for the entire reservoir	1.	118 (30.5)	53 (30.2)	74 (32.7)	1066 (120.0)	754 (90.9)	588 (97.1)	960 (103.9)	722 (162.6)	528 (225.9)	255 (90.2)	77 (33.6)	264 (53.9)
	2.	569 (172.1)	365 (209.7)	648 (95.1)	766 (107.4)	519 (100.2)	531 (134.6)	506 (96.7)	554 (308.3)	Nc	Nc	Nc	247 (41.6)

Figures in parenthesis indicate weight in grams per M^2.

Nc = Not collected.

N = Negligible.

Insects : The group was predominant in Zone I, second predominant in Zones II and III and relatively poor in Zone IV.

The number of chironomids (Tendepes spp.) was significantly high only at Centre D (Zone III), while the may-fly nymphs (Pentagenia spp.) were high in Zone I, being conspicuously poor in other centres.

In general, the group was abundant between September to March and rare in April. The details of their seasonal variations and abundance are given in Figs. 5 a & b.

By far the predominant forms among insects were dipterans and Tendepes larvae. They were on an average 22 units/sq m with a maximum of 38 units in December in Zone I, 19-77 units with a maximum range of 173-230 units in February and September in Zone II, 192-345 units with a maximum range of 1440-2016 in December and April in Zone III and 58 units with a maximum of 115 units in January in Zone IV.

Oligochaetes : Aquatic oligochaetes (Tubifex spp.), though present in all the zones, were most abundant in Zone II followed by III, IV and I in decreasing order. Seasonal abundance is shown in Figs. 5 a & b.

Prawns : Prawns [Leander spp (?)], the least dominant group of bottom macrofauna, were recorded only in Zones II and III. While a decreasing trend both in numbers and weight from the first to the second year was observed in Zone II, prawns were recorded only in the first year in Zone III. Their averages ranged from 9-38 units with a maximum of 54 units/sq m in January in Zone II.

Riverine Zone (I) : Centre A

On an average, bottom fauna decreased in dominance from 378.6 units/31.2 gm to 294.2 units/25.8 gm/sq m from the first to the second year. Insects were the most dominant group.

However, the peaks during October in the two years differed indicating 66.4% insects (may-fly nymphs) and 33.6% bivalves (Corbicula spp) in the first and 80.0% bivalves and 20.0% insects in the second year.

Admixture Zone (II) : Centres B & C

The abundance of bottom fauna in this zone was 534.2 units/72.5 gm and 496.3 units/52.4 gm/sq m during the first and second years. Molluscs dominated forming 45.7% by numbers during the first year, while the insects dominated in the second year forming 47.0% by numbers.

Shallower Zone (III) : Centres D & E

This Zone was the most productive zone of the reservoir and had 552.2 units/112.2 gm in the first year and 600.8 units/100.0 gm/sq m in the second year.

Deeper Zone (IV) : Centres F & G

The abundance of bottom fauna in this zone was 538.6 units/173.3 gm/sq m in the first year and 640.4 units/410.2 gm/sq m in the second year, recording an increase both by number and weight in the second year.

Of these, molluscs were the most dominant group, ranging from 515.6-557.0 units/170.8-404.6 gm/sq m during the two years followed by oligochaetes(14.8-62 units/1.8-4.8 gm/sq m) and insects (8.2-21.4 units/0.7-0.8 gm/sq m).

PLANKTON

A swarm of zooplankton, represented by the protozoan Ceratium in April at Centre D and Centre F, and a bloom of algae (green algae) in December was observed all over the reservoir. Phytoplankton showed an inverse relation with abundance of zooplankton (Fig. 6 & 7). When Ceratium swarmed in April, silica was found inversely related to it. In

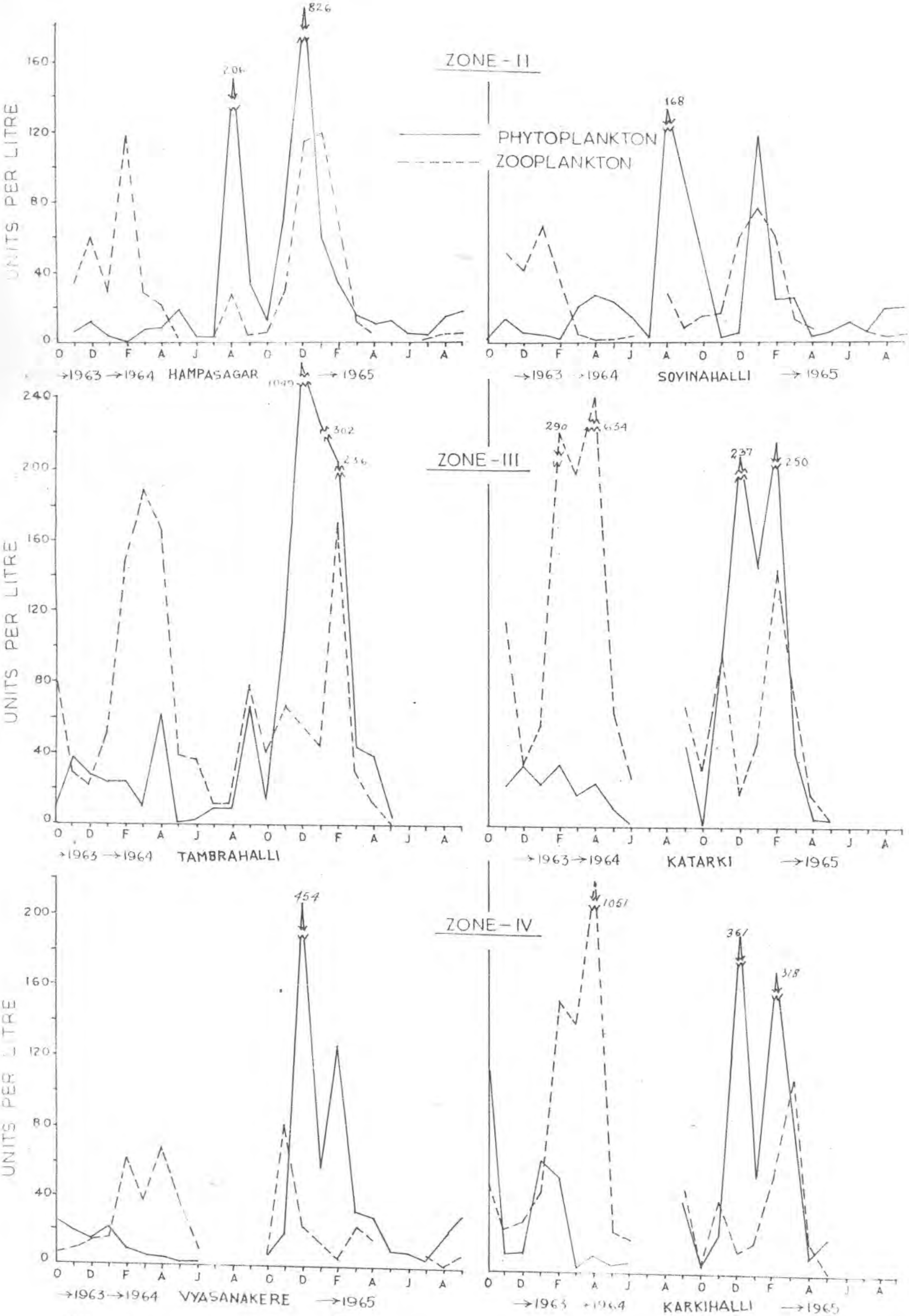


FIG- 6

PHYTO AND ZOOPLANKTON FLUCTUATIONS (MONTH TO MONTH) AT EACH OBSERVATION CENTRE

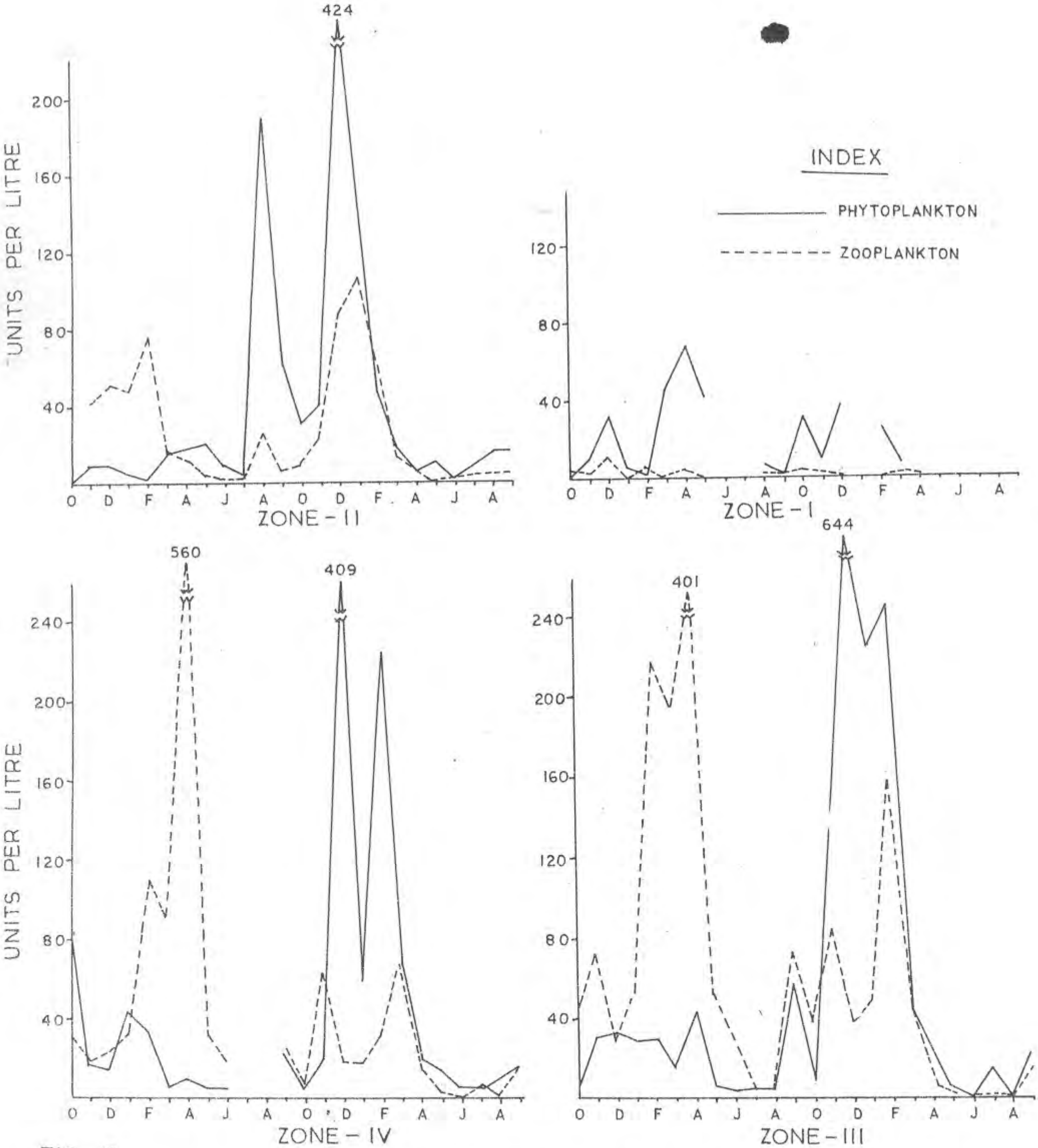


FIG. 7.

PHYTO AND ZOOPLANKTON AVERAGES (MONTH TO MONTH) TO INDICATE PLANKTON PRODUCTIVITY IN VARIOUS ZONES.

general, there was an increasing trend in units of phytoplankters per litre from October to February which coincides with the basic productivity values. Total phytoplankton numbers were 26.6% and zooplankton 73.4% in the first year but in the second year phytoplankton (50.5%) showed an improvement over zooplankton (46.5%). During the first year, the following group distribution was observed in the reservoir, Myxophyceae: 7.3%; Diatomaceae: 11.7%; Chlorophyceae: 7.6%; Protozoa: 30.7%; Rotifera: 14.8%; Cladocera: 5.2% and Copepoda 23.2%. During the second year the distribution picture was : Myxophyceae: 19.5%; Diatomaceae: 5.2%; Chlorophyceae: 31.8%; Protozoa: 18.2%; Rotifera: 8.4%; Cladocera 3.3% and Copepoda: 13.6%.

Phytoplankton

Riverine Zone (I) : Centre A

In this zone of the Tungabhadra reservoir, phytoplankton dominance was noted throughout. The ratio of zooplankton to phytoplankton in this centre was 1:7 in the first year (October '63 - September '64) and 1:12 in the second year (October '64 to September '65). Phytoplankton showed two peaks in December (33 units/l) and April (68 units/l) in the first year, Diatomaceae forming 66.6% or 14 units/l. In the second year Chlorophyceae formed 40.0% (10 units/l). The other groups of phytoplankton were Myxophyceae 9.6% (2 units/l) and Chlorophyceae 23.8% (5 units/l) and 24.0% (6 units/l) and 28.0% (7 units/l) in the first and the second years respectively.

Total phytoplankton population showed an increase in November '63 (10 units/l) reaching a maximum in December (33 units/l) forming the first peak, while the second peak of the first year was observed in April '64 (68 units/l). Subsequent to the second peak the density of phytoplankton was reduced in September '64 (1 unit/l) to rise again to form the first peak of the second year in December '64 (38 units/l). The second peak of the second year was in February (27 units/l) (Table 9).

Table 9.

Monthly fluctuations of phyto and zooplankton in various zones of the reservoir

	Oct. 63	Nov.	Dec.	Jan 64	Feb	Mar	Apr.	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 65	Feb	Mar.	Apr	May	Jun	Jul.	Aug.	Sep. 65
Zone I : Centre A																								
Myxophyceae	-	-	3	1	-	11	2	2	-	-	2	-	10	7	1	-	10	2	-	-	-	-	-	-
Diatomaceae	1	10	12	5	-	33	42	34	-	-	4	1	2	1	10	-	15	5	-	-	-	-	-	-
Chlorophyceae	-	-	18	-	2	1	24	5	-	-	1	-	20	2	27	-	2	1	-	-	-	-	-	-
	1	10	33	6	2	45	68	41	-	-	7	1	32	10	38	-	27	8	-	-	-	-	-	-
Protozoa	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifera	-	2	9	1	3	1	-	-	-	-	1	1	-	3	2	-	-	-	-	-	-	-	-	-
Cladocera	2	-	-	-	1	-	1	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-
Copepoda	1	-	2	-	1	-	1	-	-	-	1	1	-	1	-	-	-	1	-	-	-	-	-	-
	3	2	11	1	5	1	4	-	-	-	2	2	2	4	3	-	-	1	-	-	-	-	-	-
Zone II : Centres B & C																								
Myxophyceae	-	4	4	3	-	1	3	4	1	2	4	56	14	10	40	60	14	8	2	4	-	1	2	-
Diatomaceae	1	5	3	1	1	11	7	6	1	1	126	2	4	2	23	9	10	8	4	5	2	4	14	14
Chlorophyceae	-	1	3	1	1	3	8	11	7	1	58	5	12	29	361	88	24	2	-	2	-	3	-	3
	1	10	10	5	2	15	18	21	9	4	188	63	30	41	424	157	48	18	6	11	2	8	16	17
Protozoa	-	-	-	13	49	1	1	1	-	-	-	-	-	-	1	3	4	1	-	-	-	-	2	-
Rotifera	-	14	22	23	15	2	2	1	-	1	11	2	4	7	55	70	50	7	2	-	-	2	1	5
Cladocera	-	11	16	4	3	8	5	1	-	-	-	1	2	1	6	13	5	3	3	-	1	-	-	-
Copepoda	-	17	13	8	10	6	5	2	2	1	16	4	5	15	25	17	5	3	2	-	-	2	2	-
	-	42	51	48	77	17	13	5	2	2	27	7	11	23	87	103	64	14	7	-	1	4	5	5

Contd..............

Table 9 (contd.)

	Oct. 63	Nov	Dec	Jan 64	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 65	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep 65
Zone III : Centres D & E																								
Myxophyceae	3	23	20	5	10	9	31	1	1	1	1	6	6	97	19	127	191	39	19	2	-	-	-	1
Diatomaceae	-	5	8	23	17	3	8	1	1	3	4	4	1	3	25	9	29	3	3	-	-	11	-	18
Chlorophyceae	1	2	4	1	3	3	5	4	2	1	-	48	1	2	600	88	24	2	-	2	-	3	-	3
	4	30	32	29	30	15	44	6	4	5	5	58	8	102	644	224	244	44	22	4	-	14	-	22
Protozoa	-	1	1	6	42	73	263	-	-	-	-	-	-	2	-	5	41	31	-	-	-	-	-	-
Rotifera	3	17	4	15	101	38	51	2	1	-	-	30	7	23	15	34	95	8	4	-	-	1	-	1
Cladocera	9	4	2	1	3	24	15	19	6	1	-	5	2	1	1	1	4	-	2	2	-	-	-	1
Copepoda	32	51	21	35	72	59	72	31	25	4	5	38	27	58	21	8	17	10	9	1	-	-	-	13
	44	73	28	57	218	194	401	52	31	5	5	73	36	84	37	48	157	49	15	3	-	1	-	15
Zone IV : Centres F & G																								
Myxophyceae	7	7	6	7	16	2	3	1	1	-	-	2	3	20	77	45	193	50	17	10	3	1	2	-
Diatomaceae	39	8	5	36	14	2	3	1	1	-	-	2	-	1	15	2	18	8	2	2	2	1	6	11
Chlorophyceae	33	1	3	-	3	-	2	3	3	-	-	18	2	-	317	9	12	13	1	2	-	2	2	6
	79	16	14	43	33	4	8	5	5	-	-	22	5	21	409	56	223	71	20	14	5	4	10	17
Protozoa	-	-	-	2	28	34	454	-	-	-	-	2	-	-	-	1	4	39	1	-	-	-	-	-
Rotifera	14	2	4	7	32	24	29	2	3	-	-	10	2	22	13	7	18	8	6	-	-	2	-	-
Cladocera	2	1	2	2	3	6	23	10	3	-	-	-	-	1	-	-	1	2	1	-	-	-	-	8
Copepoda	16	14	16	22	46	25	54	20	12	-	-	12	3	40	5	9	8	19	9	1	-	3	2	9
	32	17	22	33	109	89	560	32	18	-	-	24	5	63	18	17	31	68	17	1	-	5	2	17

Admixture Zone (II) : Centres B & C

This zone too on an average showed predominance of phytoplankton over zooplankton, the ratio of zooplankton to phytoplankton being 1:12 in the first year. The average numbers of phytoplankters were 30 and 58 units/l respectively in the first and second year, the composition being Myxophyceae, 23.4% (7 units); Diatomaceae, 49.2% (14 units) and Chlorophyceae, 29.4% (9 units) in the first year and 30.0% (13 units), 19.0% (8 units) and 51.0% (37 units) in the second year respectively.

Diatomaceae was represented mainly by Synedra and Fragillaria each forming 22.2% of total phytoplankton in the first year and 8.7% and 5.0% in the second year. On the other hand, Chlorophyceae and Myxophyceae which dominated in the second year were represented by Hormidium (32.2%), Mougeotia (10.3%), Pediastrum (2.0%), Microcystis (13.5%), Oscillatoria (5.3%) and Anabaena (2.3%).

Considerable increase in phytoplankton peak in August was contributed mainly by epiphytic diatoms, which evidently were brought into the reservoir by rain washings. There subsequent increase within the reservoir may be due to the presence of silica which could have been utilised by the diatoms in a medium of nitrogen and iron in a temperature range of 27-29° C for multiplication. The enormous increase of Chlorophyceae in December is as stated earlier due to manurial rich marginal inundations.

Shallower Zone (III) : Centres D & E

This zone was the most productive zone within the reservoir, having an average phytoplankton concentration of 25 units/l in the first year and 132 units/l in the second (Figs. 7 & 8). In the first year, it was dominated by zooplankton (82.5%) mainly due to swarms of zooplankton in April, while in the second year phytoplankton (75.0%) dominated over zooplankton (25.0%). Phytoplankton dominance in the second year was influenced by a general algal bloom in December observed in the reservoir. The composition of phytoplankton groups was Myxophyceae 43.8% (10 units/l), Diatomaceae 27.0% (6 units/l) and Chlorophyceae 29.2% (7 units/l) in the first year, 42.8% (50 units/l), 6.7% (10 units/l) and 50.5% (72 units/l) in the second year respectively.

Myxophyceae was represented mainly by Microcystis (27.4%), Oscillatoria (7.1%) and Coelosphaerium (7.1%) of the phytoplankton averages.

Chlorophyceae was represented by Mougeotia (11.7%), Pediastrum (7.7%) and Spirogyra (2.0%); Mougeotia was present in all the months with its maximum (61 units/1) in September at Centre E.

Diatomaceae consisted of Synedra (11.7%) and Fragillaria (4.9%), which were the most frequently encountered genera.

Deeper Zone (IV) : Centres F & G

This zone comprising the deepest zone of the reservoir had an average maximum depth of 19 meters, and revealed a predominance of zooplankton over phytoplankton in the ratio of phyto to zooplankton as 1.0:3.5 in the first year. However, in the second year zooplankton was predominated over by phytoplankon (1.0:3.5). The average number of phytoplankters in this zone was 23 units/l in the first year and 79 units/l in the second year. In the first year Myxophyceae formed 21.7% (5 units/l), Diatomaceae 47.8% (11 units/l) and Chlorophyceae 30.5% (7 units/l) while during the second their respective percentage were 49.3% (39 units/l), 8.9% (7 units/l) and 41.8% (33 units/l). While Diatomaceae dominated in the first year, Myxophyceae was more abundant during the second. In the first year, Synedra (29.9%), Melosira (11.0%) and Fragillaria (8.0%) and in the second year Anabaena (27.8%) and Oscillatoria (12.8%) were conspicuous.

Diatomaceae was represented mainly by Synedra (6.0%) and Fragillaria (1.4%).

The relatively high concentration of phytoplankton between October to February in both the years can be attributed to the stable, undisturbed conditions of water, permitting maximum transparancy and ideal conditions of temperature ranging from 23.0°C to 24.0°C. The reduction in phytoplankton concentration from March onwards may be due to the grazing effect of zooplankton and other higher forms over phytoplankton and an increase in temperature.

Considering the relative richness of the various zones during the two years with regard to phytoplankton, Zone III comprising the Shallow Zone was found to be the richest while the Riverine Zone (I) was the poorest. The average plankton density during the two years showed that Zone II was 2.0 times,

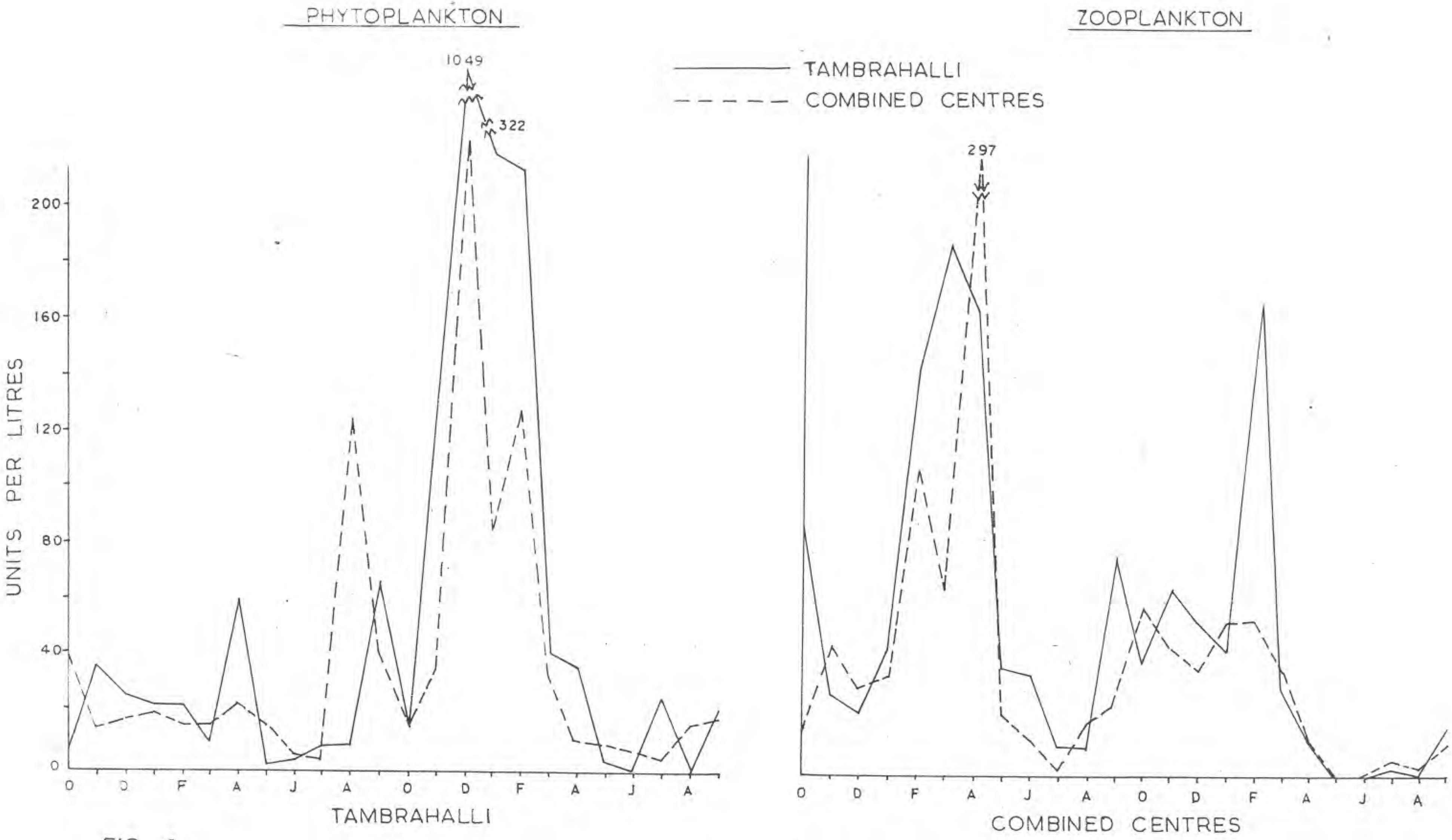


FIG. 8

PLANKTON VARIATIONS BETWEEN THE MOST PRODUCTIVE TAMBRAHALLI BAY *VERSUS* ALL OTHER CENTRES.

Zone IV 2.3 times and Zone III 4.5 times richer than Zone I. The productive part of the year with reference to phytoplankton production in the reservoir has been found to be immediately after the South-West monsoon from the end of August to February with a succession of groups.

A list of phytoplankters recorded in the different zones is given in Table 10.

Zooplankton :

In general, zooplankton had higher peaks in summer months. Their greatest abundance was recorded in Zone III (118 units/l) and IV (95 units/l) respectively, contributed mainly by the protozoan Ceratium. Protozoans, rotifers, cladocerans, copepods and rarely ostracods (Table 10) constituted the major groups. Considering the reservoir as a whole, protozoans formed 41.8% of the zooplankton population and were the most dominant followed by copepods (31.3%), rotifers (19.4%) and cladocerans (7.5%) during the first year and rotifers (46.2%), copepods (34.6%), protozoans (15.4%), and cladocerans (3.8%) during the second year.

Protozoa :

Protozoans were mainly found in Zones III and IV, gradually increasing in numbers from January to April. The maximum numbers were represented by the genus Ceratium at Centres D (515 units/l) and F (900 units/l). The maximum number of protozoans was 2 units/l (April) in Zone I, 49 units/l (February) in Zone II, 263 units/l (April) in Zone III and 454 units/l (April) in Zone IV during the first year while in the second year the maximum numbers were 4 units/l (February) in Zone II, 41 units/l (February) in Zone III and 39 units/l (March) in Zone IV. The average number of protozoans in different zones was 6 and 1 units/l in Zone II, 42 and 8 units/l in Zone III, and 52 and 5 units/l in Zone IV during the first and the second years respectively. In both the years, protozoans in Zone I were so low as to be considered negligible while considering the annual averages. The various genera noted in order of abundance were Ceratium, Gonium, Difflugia, Actinophrys and Euglena.

Table 10

A list of the plankton organisms recorded from the various zones of the Tungabhadra Reservoir.

(1963-65)

Centre	Zone I	Zone II		Zone III		Zone IV	
	A	B	C	D	E	F	G
PHYTOPLANKTON							
MYXOPHYCEAE							
1. *Microcystis*	x	x	x	x	x	x	x
2. *Merismopedia*	x	x	x	x	x	x	x
3. *Phormidium*	x	-	-	x	x	x	x
4. *Coelosphaerium*	x	x	x	x	x	x	x
5. *Stigonema*	x	x	x	x	x	x	x
6. *Clathrocystis*	x	-	x	-	-	-	-
7. *Anabaena*	x	x	x	x	x	x	x
8. *Oscillatoria*	x	x	-	x	x	x	x
9. *Aphanocapsa*	-	x	x	x	x	x	x
DIATOMACEAE							
10. *Synedra*	x	x	x	x	x	x	x
11. *Fragilaria*	x	x	x	x	x	x	x
12. *Gyrosigma*	x	x	x	x	x	x	x
13. *Amphora*	x	-	-	-	-	x	-
14. *Navicula*	x	x	x	x	x	x	x
15. *Nitzschia*	x	x	x	x	-	-	-
16. *Tabellaria*	x	x	-	-	-	x	-
17. *Surirella*	x	-	x	x	x	x	x
18. *Diatoma*	-	-	-	-	-	-	x
19. *Melosira*	-	x	x	x	x	x	x
20. *Cocconeis*	-	-	-	-	-	-	x
21. *Achnanthes*	-	-	-	x	-	-	-
22. *Coscinodiscus*	-	-	-	-	-	-	x
23. *Cymbella*	x	x	-	x	-	-	x

x = Recorded. - = Not recorded.

contd......

Centre	Zone I	Zone II		Zone III		Zone IV	
	A	B	C	D	E	F	G
24. Asterionella	-	-	-	x	-	-	-
25. Pleurosigma	-	x	-	x	-	-	x
26. Gomphonema	-	-	-	-	-	x	x
DESMIDS							
27. Cosmarium	-	x	-	x	-	x	x
28. Closterium	-	x	x	x	x	x	-
29. Staurastrum	-	-	-	-	-	-	x
CHLOROPHYCEAE							
30. Ankistrodesmus	-	-	-	x	-	x	x
31. Spirogyra	x	x	x	x	x	x	x
32. Oedogonium	x	-	x	x	x	-	x
33. Pediastrum	x	x	x	x	x	x	x
34. Mougeotia	x	x	x	x	x	x	x
35. Hormidium	x	x	x	x	x	x	x
36. Scenedesmus	-	-	-	-	-	-	x
37. Bumelleria	x	x	x	-	-	x	-
38. Zygnema	-	-	x	-	-	-	-
39. Cylindrocystis	-	x	-	-	-	-	-
40. Tetraspora	-	x	-	-	-	-	-
41. Chaetophora	-	-	-	-	-	x	-

x = Recorded. - = Not recorded.

-contd......

Centre	Zone I	Zone II		Zone III		Zone IV	
	A	B	C	D	E	F	G
ZOOPLANKTON							
PROTOZOA							
1. Ceratium	x	x	x	x	x	x	x
2. Gonium	-	x	-	x	-	-	-
3. Actinophrys	-	x	-	x	-	x	[illegible]
4. Arcella	-	-	-	x	x	-	-
5. Difflugia	-	-	-	x	-	-	x
6. Euglena	-	-	-	-	x	-	x
ROTIFERA							
7. Brachionus	x	x	x	x	x	x	x
8. Keratella	x	x	x	x	x	x	x
9. Triarthra	x	x	x	x	x	x	-
10. Polyarthra	x	x	x	x	x	x	x
11. Schizocerca	x	-	-	x	x	x	-
CLADOCERA							
12. Chydorus	x	x	x	x	x	x	x
13. Diaphanosoma spp. (2)	x	x	x	x	x	x	x
14. Bosminopsis	-	-	-	-	x	-	-
COPEPODA							
15. Nauplius	x	x	x	x	x	x	x
16. Copepodid stages of Cyclops	x	x	x	x	x	x	x
17. Cyclops	x	x	x	x	x	x	x
18. Copepodid stages of Diaptomus	x	x	x	x	x	x	x
19. Diaptomus	x	x	x	x	x	x	x
OSTRACODA	-	-	-	-	-	-	x

x = Recorded. - = Not recorded.

Rotifera :

Rotifera was the third (19.4%) dominant group in the first year and the first (46.2%) in the second year. In general, they were abundant during the summer months (February-May) except in Zone I and II where they appeared during December-January.

The group was represented by Keratella, Brachionus, Triartha, Polyarthra, Schizocerca and Noteus in order of their abundance. However, Keratella was the most dominant of all being 66 and 84 units/1 in February at Centre E, and 113 and 73 units/1 in February at Centre D respectively during the two years.

Cladocera :

The group was poorly represented in all the zones, being 4, 8 and 5 units/1 in Zones II, III and IV respectively during the first year, and 1, 3, 1, 1 units/1 in Zones I, II, III and IV respectively during the second year.

Cladocera was represented by Chydorus, Diaphanosoma, Bosminopsis and rarely Daphnia, in order of abundance. Chydorus was at its maximum (31 units/1 in March) at Centre D followed by 26 units/1 in April at Centre F, 18 units/1 in December at Centre C, 15 units/1 in March at Centre E and 2 units/1 at Centre A during the first year. However, it was poorly available during the second year. Diaphanosoma was at its maximum (15 units/1 in May) in Zone III followed by 13 units/1 (April) in Zone IV (Centre F) during the first but was negligible during the second year.

Copepoda :

Copepoda was the most frequently encountered group of zooplankton, being next only to Protozoa and Rotifera during the two years and was mainly represented by nauplii, copepodite stages and a few adults of Cyclops and Diaptomus.

The larval stages of copepods were more abundant than the adults. The group was at its maximum (113 units/1 in February) in Zone III (Centre D) followed by 74 units/1 (April) in Zone IV (Centre F), 20 units/1 (November-December) in Zone II (Centre

C) and 2 units/l in Zone I during the first year, and 72 units/l (November) in Zone III (Centre D), 58 units/l (November) in Zone IV (Centre G), 40 units/l (December) in Zone II (Centre C) and 1 unit/l (March) in Zone I during the second year.

Ostracoda :

Ostracods, represented by Cypris, occurred very rarely being 2 units/l in November, December and January in Zones II and III during the second year.

FISH FOOD PRODUCTION TRENDS

Littoral and Bottom Biota

A study of the production of littoral and bottom biotal organisms reveals that molluscs and insects are the most dominant groups. Of the former group, while the gastropods dominated over the entire range, bivalves were dominant at centres B and C (Zone II). Insects were predominant at Centre A (Zone I) and at D (Zone III), with the only difference that at Centre A, mayfly nymphs (fluviatile) and at D, chironomid larvae, dominated. The sandy and flowing conditions, and the soft, organically rich, muddy bottom respectively determined these features. Tubificids were present all over the reservoir in small numbers.

A dark-brown, moderately rich soil with high calcium (2000-4000 lb/acre) and magnesium (600-1000 lb/acre) in addition to moderate concentration of soluble salts (sp. cond. 77-124 x 10^{-6} mhos) and 10 to 13% organic matter could harbour considerable populations of insects (195-337 units/sq m), bivalves (22-93 units/sq m) and oligochaetes (6-19 units/sq m) in Zones I and II. Since Corbicula spp. and mayfly nymphs (Pentagenia spp.) prefer mainly the fluviatile environment and highly oxygenated sandy conditions, they dominated in these two zones. The easily displaceable, loose sandy bed, with fine colloidal particles within the interstices of sandy bottom encouraged their colonisation. The effect of slow rate of drawdown was that the forms could easily slide into preferred depths without danger. This sustained their population more or less in a stable condition.

The Shallower Zone (III), comprising the Tambrahalli, Katharki and numerous smaller bays, was the richest both in chemical constituents and littoral-bottom organisms. A predominant molluscan life (283-340 units/sq m) was possible when it was noted that 4000-6000 lb/acre calcium and 1000-2000 lb/acre magnesium salts were present, with concomitant pH (8.0-8.5) and specific conductivity (100-153 x 10^{-6} mhos). The very nature of these outer bays, which were stagnant when full and exposed to sunlight for 4-6 months, added to the fertility of the soil and water on refilling.

In the Deepest Zone (IV), molluscs in general dominated (516-557 units/sq m), of which gastropods (373-391 units/sq m) were the most significant as their presence was recorded even in the deeper protions. As the shells are liable to be washed from deeper layers to the margins and back due to wave action, a considerable accumulation of lighter dead shells occurred in the Zone.

Bottom Biota in relation with soil features

Observations in the various zones during 1963-65 have shown that molluscs and insects were the most dominant components of the bottom biota. Of the molluscs, gastropods in general dominated over the entire range, bivalves dominating at Centres B, and slightly so at C (Zone II). Gastropods showed an inverse distributory trend with the bivalves. Insects were predominant at Centres A and D, with the difference that at the former centre the group comprised mayfly nymphs, while at the latter centre chironomid larvae predominated. Prawns and aquatic oligochaetes (Tubifex spp.) were in negligible numbers, the former being localised at Centres B, C and D, while the latter were present all over the reservoir with maximum numbers at Centre B. An almost similar trend with a slight deviation at all centres was noted in the second year also.

Zone I & II (Riverine Centre A, and Admixture Zone Centres B & C)

Of the two zones, Zone I was predominantly insect populated (195-337 units/sq m). Since bivalves (Corbicula spp.) prefer mainly fluviatile conditions where better oxygenation and sandy substrata are found, they were also available in the zone. Flushing of finer colloidal particles and deposited food from the interstices of sand layers and creation of a certain flow of water due to draw-down helped their colonisation in Zone II also. These zones were thus ecologically well suited for the forms. An increase in turbidity due to prevailing windy conditions caused a gradual increase in the numbers of aquatic worms. Prawns were rarely found in Zone II in bottom samples, even though they concentrate at the fluctuating river junction with the main reservoir in a length of nearly 3.5 to 4.0 km between January and April.

Zone III

In general, Zone III was the richest, both in its chemical constituents as also bottom biota. The richness of this zone with a predominance of molluscs (293-340 units/sq m) is obvious when it is noted that minerals like calcium (4000-6000 lb/acre) and magnesium (1000-2000 lb/acre) were also quite high in the soil, which in addition had a pH of 8.0 to 8.5 and specific conductivity 100-153 x 10^{-6} mhos.

Zone IV

Molluscs dominated (516-557 units/sq m) in this zone during the two years, gastropods being significantly high in numbers (373-391 units/sq m) than the other groups. This is an indication that when the marginal water of this zone becomes turbid by wind action in April and May and consequently perhaps slightly richer in nutrient salts, the mud-water interphase seems to confer an advantage to the gastropods for thriving.

Plankton in relation to water conditions

In general, plankton concentration in Zone I was low (7-38 units/litre), except in April '64, when it was 68 units/litre, contributed mainly by the epiphytic diatoms which accounted for more than 50.0% of the density. Such forms dominated this zone because of the riverine conditions.

Concentration of plankters in Zone II was almost similar to Zone I with occasional spurts (August) due to epiphytic diatoms dislodged by a fresh incursion of rain-water, aided by strong wind agitation on the littoral margins. The sudden 'bloom' of algae in December contributed mainly by Chlorophyceae may be due to inundation of the rich arable lands earlier in September-October. Though it is likely that much of the nutrients so released might be washed off from the reservoir during August-September, it is only after the floods stop in September that stable reservoir conditions appear enriching planktonic growth by November-December. This conclusion is supported by the similarity in pattern of appearance of algae in the surrounding seasonal and perennial tanks which over-flow once or twice by September. The sharp plankton fall subsequently is supported by a corresponding fall in water level. The gradual decline in the density of zooplankton in March-April coincides with an increase in wind velocity and high temperature until July.

The abundance of phytoplankton in Zone III from November to April with a maximum in April is contributed by Myxophyceae and finds a positive correlation with the increase in all the chemical constituents like alkalinity, hardness, sp. conductivity, chloride, silica and nitrate. Samplings in the month of May being close to the mouths of the original bays show poor concentrations of plankton. The gradual rise from August indicate the recovery period, which reaches a maximum in December. While the abundance of phytoplankton, dominated by Chlorophyceae, in December is caused by the inundations as mentioned earlier, the increased presence of Myxophyceae up to February is probably due to optimum temperatures and slight organic contamination.

Zooplankton abundance during February-April in Zone III is mainly due to Rotifera (43.3%) at Centre E and Protozoa at Centre D (61.7%). Centre E with its perennial river (Chikkhagari) shows a variation in plankton composition when compared with Centre D with its seasonal river (Hirehalla) drying up.. The turbid waters of Centre D, caused by wind action, possess a higher concentration of Protozoa than Rotifera which are much higher at Centre E where wind action is modified by physical barriers such as the hillocks. In general, there was a positive correlation between the increase in some of the chemical constituents like alkalinity, sp. conductivity and silica and the abundance of zooplankton. The summer period (May-July) showed the lowest concentrations of plankton, the high temperatures and turbulences probably accounting for such a decline. In September (recovery period), an increase in zooplankton was caused by rotifers when the water became relatively clear following cessation of the floods.

Phytoplankton abundance in October and January in Zone IV was caused by the epiphytic diatoms released from the marginal areas during high water levels. The December peak was constituted mainly by Chlorophyceae (<u>Hormidium</u> spp.) extraneously brought into the reservoir by inundations and supplanted by Myxophyceae which increase in February after the decline in the percentage of Chlorophyceae which appear to be washed away with the outflow (supported by collection of the riverine centre below the Dam). The low concentration of important chemical constituents in February than in April and May in this zone appears to favour the growth of Myxophyceae, which could utilise them only in the absence of Chlorophyceae. This indicates that the real stable phytoplankton population of the reservoir is, perhaps, Myxophyceae. Subsequent to March, when the temperature and water turned organically rich by the homogeneous churning by wind action, the conditions became more suitable for zooplankton abundance than phytoplankton.

Zooplankton abundance in Zone IV was similar to that of the Shallow Zone during February to May, the peak of April differing somewhat in being mainly contributed by the Centre F (Protozoan <u>Ceratium</u>) than the Centre G. If Centre G alone is considered, the abundance is mainly due to Rotifera which are common to the Deeper Zone in general. The chemical constituents were relatively low in this zone until April. From May to July, the nutrient items indicated better concentrations aided by high temperatures, maximum disintegration of bottom sediments occurred. In addition, nutrients washed into this zone from the upper reaches also created favourable conditions. But instead of its resulting in an abundance of plankton, this zone actually tended to show lower values. It is difficult to explain what inhibitory causes prevailed within such an open water zone. Super-imposition of several layers of suspensoids, forming considerably thick layers of muck at the mouths of the bays as also in the Deeper Zone where the contour is sharply precipitous, need confer no richness in nutrients to the overlying waters.

PART II.

FISHERIES BIOLOGY

FISHES OF THE TUNGABHADRA RESERVOIR

The fish fauna of the Tungabhadra reservoir comprises species endemic to the Krishna river system and is essentially that of the Peninsular Indian forms rather than those known for their high commercial value. 79 species were identified and probably three to four more species of the genera Garra and Nemacheilus may be available (Table 11). However, all the Krishna-Godavari river forms were not found in the reservoir proper. Of the 79 species, only 35 form bulk of the catches in the reservoir.

Table 11

A list of fishes recorded from the Tungabhadra reservoir and the river below the Dam

	Scientific name	Local name (Kannada)
Order CLUPEIFORMES		
Suborder NOTOPTEROIDEI		
Family NOTOPTERIDAE		
	1. Notopterus notopterus (Pallas)	Chappali-meenu
Order CYPRINIFORMES		
Division Cyprini		
Suborder CYPRINOIDEI		
Family CYPRINIDAE	2. Chela atpar (Hamilton)	
	3. Oxygaster argentea (Day)	Mallimeen or Orali
	4. Oxygaster clupeoides (Bloch.)	
	5. Oxygaster phulo (Hamilton)	"

contd....

6.	Barilius bendelisis (Hamilton)	Bilacha
7.	Barilius barila (Hamilton)	
8.	Barilius barna (Hamilton)	
9.	Danio aequipinnatus (McClell.)	
10.	Esomus danrica (Hamilton)	
11.	Rasbora daniconius (Hamilton)	
12.	Amblypharyngodon mola (Hamilton)	
13.	Aspidoparia morar (Hamilton)	
14.	Tor khudree (Sykes)	Bilimeenu
15.	Tor mussullah (Sykes)	"
16.	Puntius sarana (Hamilton)	Gende
17.	Puntius pulchellus (Day)	Harigi
18.	Puntius dobsoni (Day)	"
19.	Puntius chola (Hamilton)	
20.	Puntius kolus (Sykes)	Kolacha
21.	Puntius dorsalis (P. puckelli) (Hora)	Sanna-gende
22.	Puntius amphibia (V.)	
23.	Puntius ticto (Hamilton)	
24.	Puntius ambassis (Day)	
25.	Puntius sophore (Hamilton)	
26.	Puntius narayani (Hora)	
27.	Catla catla (Hamilton)	
28.	Cirrhinus mrigala (Hamilton)	
29.	Cirrhinus reba (Hamilton)	Arja
30.	Cirrhinus fulungee (Sykes)	"
31.	Garra spp. (3)	Kallukora-va.
32.	Labeo fimbriatus (Bloch)	Kemmenu
33.	Labeo calbasu (Hamilton)	Kamma-chhalu

contd....

	34. *Labeo rohita* (Hamilton)	
	35. *Labeo porcellus* (Heckel)	Kakidindu
	36. *Labeo potail* (Sykes)	
	37. *Labeo pangusia* (Hamilton)	
	38. *Labeo bata* (Hamilton)	
	39. *Labeo boggut* (Sykes)	
	40. *Labeo boga* (Hamilton)	
	41. *Schismatorhynchus* (*Nukta*) *nukta* (Sykes)	
	42. *Homaloptera maculata* (Gunther)	Mukharti
	43. *Osteobrama vigorsii* (Sykes)	Parakemeenu
	44. *Osteobrama neilli* (Day)	
	45. *Rohtee ogilbii* (Sykes)	Sepri
	46. *Osteobrama cotio* (Hamilton)	
	47. *Osteochilus* (*Osteochilichthys*) *thomassi* (Day)	Hagari
	48. *Thynnichthys sandkhol* (Sykes)	Bangade
Family COBITIDAE	49. *Botia striatus* (Rao)	Handimeenu
	50. *Lepidocephalichthys thermalis* (Bleeker)	
	51. *Noemacheilus evezardi* (Day)	Murangi
	52. *Noemacheilus rubidipinnis* (Gunther)	
	53. *Noemacheilus* spp. (2)	

Division Siluri

Suborder SILUROIDEI

Family SILURIDAE	54. *Ompok bimaculatus* (Bloch)	
	55. *Ompok pabo* (Hamilton)	

contd....

	56. Wallago attu (Schn.)	Bale
Family SCHILBEIDAE	57. Pseudeutropius goongwaree (Gunther)	
	58. Pseudeutropius taakree(Day)	Halati
	59. Neotropius khavalchor (Kulkarni)	
	60. Silonia childrenii (Bleeker)	Bilihalati
	61. Amblyceps mangois (Hamilton)	
Family BAGRIDAE	62. Mystus aor (Hamilton)	Kappusuragi
	63. Mystus seenghala (Sykes)	Bilisuragi
	64. Mystus maydelli Rossel	Haddinameen
	65. Mystus cavasius (Hamilton)	Giralu
	66. Rita pavimentata Gunther	Gokra or kechhalu
	67. Rita hastata Gunther	
Family SISORIDAE	68. Bagarius bagarius(Hamilton)	Kuradi
	69. Gagata itchkeea (Sykes)	

Order ANGUILLIFORMES

Suborder ANGUILLOIDEI

Family ANGUILLIDAE	70. Anguilla nebulosa (Gray and Hardw) = A. bengalensis(Gray)	

Order BELONIFORMES

Suborder SCOMBERESOCOIDEI

Family BELONIDAE	71. Xenentodon cancila (Hamilton)	Kaliholaya

Order CYPRINODONTIFORMES

Suborder CYPRINODONTOIDEI

Family CYPRINODONTIDAE

72. Aplocheilus lineatum (Val.)

contd....

Order OPHIOCEPHALIFORMES

Family OPHIOCEPHALIDAE (Channidae)	73.	Channa marulius (Hamilton)	Aowlu or Kuchhu
	74.	Chana striatus (Bloch)	"
	75.	Channa punctatus (Bloch)	"
Family LABYRINTHICI	76.	Polyacanthus cupanus (Cuv. and Val.)	

Order PERCIFORMES

Suborder PERCOIDEI

Family AMBASSIDAE	77.	Ambassis nama (Hamilton)	
	78.	Ambassis ranga (Hamilton)	Bachani-gemeenu

Suborder GOBIOIDEI

Family GOBIIDAE	79.	Glossogobius giuris (Hamilton)	Bhangi

Order MASTOCEMBELIFORMES

Family MASTOCEMBELIDAE	80.	Mastocembelus armatus (Lac.)	Haavumeenu
	81.	Mastocembelus pancalus (Hamilton)	

It is reported that of the commercial forms, Catla catla (Hamilton) was originally found up to Kurnool in the Tungabhadra river. The species was undoubtedly introduced in the Krishna-Tungabhadra rivers below the Dam by the Department of Fisheries, Madras, and stray forms could have been caught in the river before the completion of the Dam. But, there is no evidence to indicate that Catla catla is indigenous to the system, though it is probably naturalised recently within the deltaic Krishna. This species alongwith Cirrhinus mrigala and Labeo rohita, occasionally recorded in the catches of the reservoir, are those introduced in small numbers as fingerlings by the Tungabhadra Board.

It is of some zoogeographical interest to mention that for the first time Labeo pangusia (Hamilton), a fish recorded originally in the Gangetic system, as well as Amblyceps mangois (Ham.), known to be distributed only up to the river Sone and the Mahanadi until now, were recorded from the Tungabhadra. Though the distribution range of L. Pangusia was extended to the Godavari-Krishna river systems during a recent survey, its presence in the Tungabhadra was confirmed only now. The small, torrential Himalayan catfish, A. mangois, was for the first time recorded so far south, and this is of immense zoogeographical interest. Presence of Homaloptera maculata (?) Gunther again is of high interest, as no Homaloptera species has been recorded so far in the Krishna-Godavari drainages though the genus was recorded earlier in the Cauvery drainages within the Western Ghats.

For the first time it has also been noted that of the genus Mystus, Mystus (Mystus) maydelli * found within the Tungabhadra river in the vicinity of the Tungabhadra reservoir is the largest growing species of the genus in India. A length of 1385 mm (t.l.), girth of 895 mm, and weight of 25,416 gm is now recorded surpassing weights of M. aor and M. seenghala, considered so far to be the largest growing representatives of the genus in Indian rivers. But M. maydelli is as infrequent in the reservoir as Bagarius bagarius and only stray captures are recorded.

FOOD AND FEEDING HABITS

The material for the study on the food and feeding habits of fishes was collected from the catches obtained during experimental fishing in the various zones almost regularly during all months of the year. The gill nets used for experimental fishing had a mesh bar size of 30, 40, 45 and 50 mm. Commercial landings by gill nets and shore seines were also examined.

The studies on the food and feeding habits were initiated in January '64 and were continued for one year. Guts of P. kolus, P. dobsoni, P. sarana, L. fimbriatus, L. calbasu, O. vigorsii and

* The form confirms with the description of the new species described by Von Fritz Rossel (1964) in Mitt. Hamburg. Zool. Mus. Inst. Vol.61 (pp. 149-151) from the Bhima river.

N. notopterus were analysed by eye-estimation and frequency occurrence methods. Among catfishes, M. seenghala, M. aor, M. cavasius, W. attu, Silonia childrenii and Pseudeutropius taakree were analysed qualitatively by volumetric method. In addition to the above, food habits of other species encountered in stray numbers in the departmental catches were also observed.

The guts and stomachs were fixed in the field in 5% formalin for examination in the laboratory. The contents were taken from pre, mid and hind-guts and the various items were identified by using a compound microscope. The percentage of each item of food was made in relation to the occurrence of abundance. Degree of fullness was expressed as being ¼ full, ½ full, ¾ full and full. In analysing the contents of catfishes with well-defined stomachs, only stomach food contents were taken into consideration. The percentage composition of food items of carps and cat fishes are shown in Fig.9.

Carps :

1. Puntius kolus

802 specimens of P. kolus ranging in size from 156-496 mm with a sex ratio of 1M : 1.2F were examined. The species formed 14.32 and 8.71% of the total commercial catches during 1964 and 1965 respectively, being the most dominant amongst carps.

The protruscible mouth in P. kolus is highly adopted to a bottom feeding habit. 272 guts forming 33.9% were empty. The relative percentage composition of the feed of P. kolus is given below :

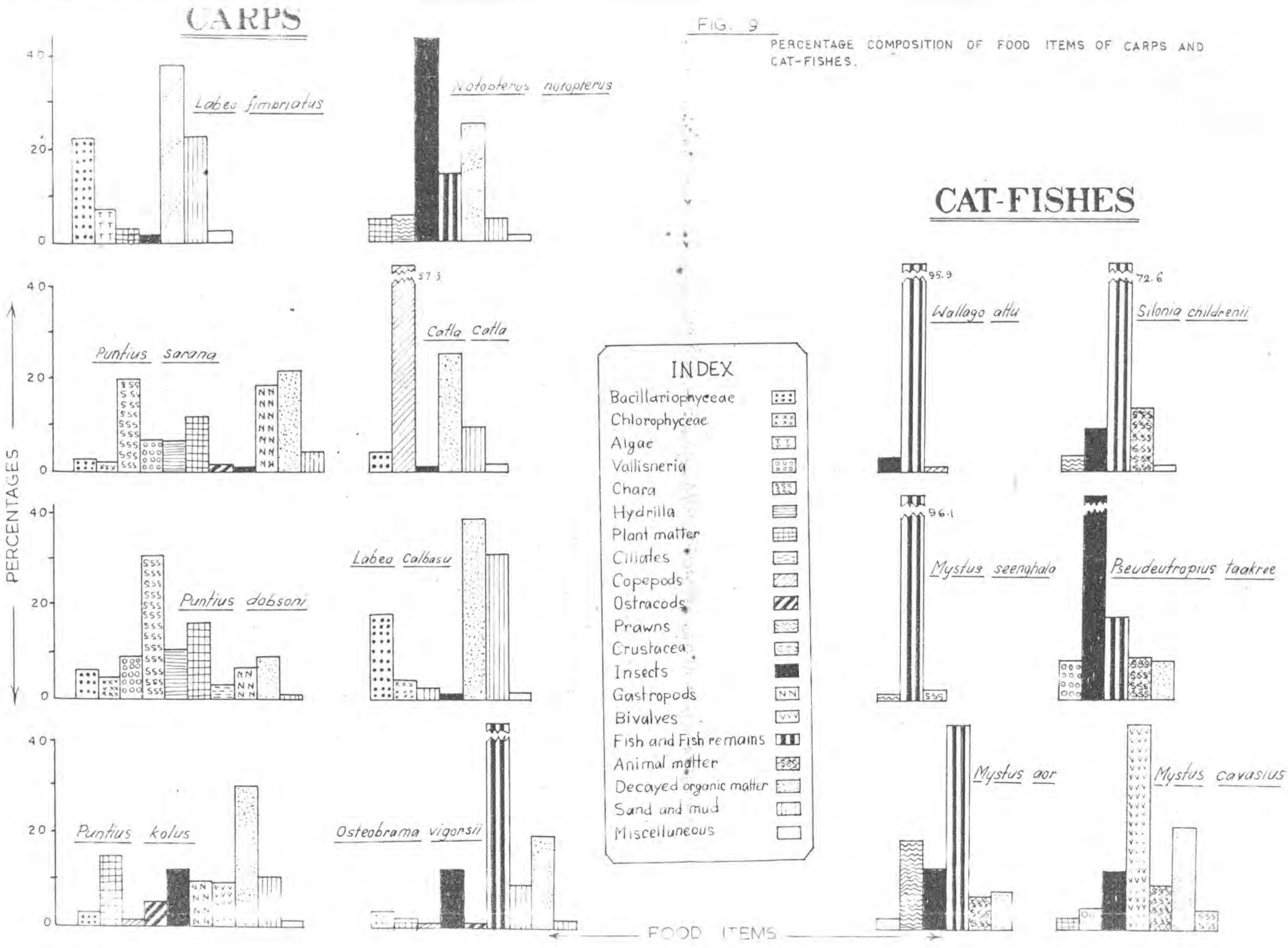
Bacillariophyceae	- 2.8%	Gastropods	- 9.8%
Chlorophyceae	- 0.1%	Bivalves	- 9.6%
Plant tissue	- 15.5%	Digested organic matter	-30.9%
Copepods	- 1.0%	Sand and mud	-11.1%
Ostracods	- 5.3%	Miscellaneous	- 1.4%
Insect matter	- 12.5%		

2. Puntius dobsoni

The species formed 4.06 and 5.30% of the total fish catches during 1964 and 1965 respectively. Guts from 120 specimens ranging in size from 250 to 745 mm in total length with

FIG. 9

PERCENTAGE COMPOSITION OF FOOD ITEMS OF CARPS AND CAT-FISHES.



1M : 1.3F sex ration were examined. Only one gut was found to be empty.

The fish being mainly herbivorous was found to ingest a high percentage of decaying and fresh vascular plants like Chara, Vallisneria, Hydrilla, Ceratophyllum and others with only a negligible proportion of aquatic algae. Most of this was only partially digested. It is however likely that partially digested plant matter thrown out contributes to the richness of the detritus. The species in being a vegetable feeder is comparable to the Chinese grass carp in food habits. An allied species, P. pulchellus, also feeds on vegetable matter; these two forms perhaps can be used for controlling vegetation in a pond. The relative abundance of food items in the guts of P. dobsoni was as follows :-

Bacillariophyceae	- 6.4%	Plant tissue	- 16.9%
Chlorophyceae	- 4.6%	Ciliates	- 3.0%
Vallisneria	- 9.6%	Gastropods	- 7.1%
Chara	- 31.6%	Digested organic matter	- 9.2%
Hydrilla	- 10.6%	Miscellaneous	- 1.0%

3. Puntius sarana

This fish contributed 1,82 and 2.30% to the total catches of the reservoir during 1964 and 1965 respectively. Guts from 211 specimens were examined in 1M : 5F sex ratio with sizes ranging from 195 to 355 mm. The species is more or less a marginal vegetative feeder, feeding upon aquatic plants like Chara, Hydrilla, Vallisneria and planktonic algae belonging to Bacillariophyceae and Chlorophyceae.

Of the 211 guts examined, 152 guts (72.0%) were empty. The percentage of various items forming the food of the species is given below :

Bacillariophyceae	2.7%	Ostracods	1.6%
Chlorophyceae	2.4%	Insects	1.1%
Chara	20.3%	Gastropods	19.1%
Vallisneria	7.0%	Mud	4.2%
Hydrilla	6.9%	Digested organic matter	22.3%
Plant tissue	12.4%		

4. Labeo fimbriatus

L. fimbriatus forms a fairly good carp fishery, next only to P. kolus on a commercial scale. It contributed to 5.34 and 7.64% of the total fishery during the years 1964 and 1965, with sex ratio of 1.7M : 1.0F. Guts of 164 specimens, ranging in size from 203-636 mm were examined, of which 71 were found to be empty. The position and protruscibility of the mouth seem to be highly adopted for bottom browsing. It is stenophagic in feeding on the types of food available in the reservoir.

The percentage of abundance of the various food items is given below :

Bacillariophyceae	22.8%	Animal matter	0.7%
Algae	7.4%	Digested organic matter	38.1%
Plant tissue	3.0%	Sand and Mud	22.9%
Copepods	0.7%	Miscellaneous	2.7%
Insect matter	1.7%		

5. Osteobrama vigorsii

O. vigorsii is one of the predominant medium sized carps which adds fairly to the bulk of the fishery value as it occurs in quite large numbers. It constituted 1.93 and 2.20% by weight of the total fishery during 1964 and 1965 respectively. 397 specimens ranging in size from 103-349 mm with sex ratio 1M : 9.4F were examined for gut studies, of which 210 were empty.

The species is undoubtedly a column and surface feeder, as supported by presence of fish and insect remains. The large eyes, up-turned mouth and strong jaws indicate its predaceous nature. O. vigorsii was found principally to feed upon other fishes, insects, animal matter, gastropods, copepods, ostracods, filamentous algae, plant tissue and Bacillariophyceae.

The abundance of various items in the food was as follows:

Bacillariophyceae	- 0.1%	Gastropods	- 1.0%
Chlorophyceae	- 3.7%	Fish remains	- 46.8%
Plant tissue	- 2.1%	Animal matter	- 9.5%
Copepods	- 1.0%	Digested organic matter	- 20.1%
Ostracods	- 0.4%	Mud	- 1.9%
Insects	- 12.9%	Miscellaneous	- 0.5%

A limited number of some other carps and N. notopterus were also examined for their gut contents, the results of which are presented below :

1. Labeo calbasu : The species formed a very minor fishery of the reservoir contributing to only 1.68 and 1.30% of the total catches during 1964 and 1965 respectively. Stray individuals were available in the commercial landings. Only 27 specimens (211-492 mm) were examined.

This fish is a bottom feeder, like L. fimbriatus. The average percentage composition of the feed of this fish was as follows :

Bacillariophyceae	- 18.7%	Digested organic matter	- 39.7%
Chlorophyceae	- 4.4%	Sand and mud	- 32.0%
Plant tissue	- 2.5%	Miscellaneous	- 1.6%
Insect matter	- 1.1%		

2. Catla catla : The species stocked in the reservoir appeared in stray numbers in the commercial catches. Of the 20 specimens (231 to 975 mm) examined, three specimens had empty guts.

C. catla is stenophagic feeding on several types of food organisms. It is generally a column-feeder. As is well known it is found to feed mainly upon planktonic copepods, Bacillariophyceae and aquatic insects.

The relative abundance of food items of this fish was as below :

Bacillariophyceae	- 4.4%	Digested organic matter	- 25.9%
Copepods	- 57.3%	Mud	- 9.7%
Insects	- 1.2%	Miscellaneous	- 1.5%

3. Puntius pulchellus : All the 10 guts, analysed from specimens ranging in size from 322 to 734 mm, revealed a predominance of gastropods (32.8%) followed by Hydrilla (19.0%), Chara (11.5%), ciliates (Paramecium spp. 3.9%), Bacillariophyceae (1.6%), digested organic matter (16.1%) and plant tissue (15.0%).

P. pulchellus is allied to *P. dobsoni*, which has been dealt in detail earlier, and shows almost little variation in its food and feeding habits and appears to be a vascular plant feeder.

4. *Tor* spp. : Both *Tor khudree* and *Tor mussulah* occurred on rare occasions in the commercial catches; only 8 specimens (275-870 mm) were examined. The species feed both on the bottom and column mainly subsisting on gastropods (56.5%), bivalves (10.0%), insect matter (11.4%), digested organic matter (15.0%) and mud (7.1%). The presence of mud in a few guts can be attributed to their having been taken along with the molluscan shells.

5. *Notopterus notopterus* : The species formed a negligible percentage both in 1964 (0.21%) and 1965 (0.50%) of the commercial fish catches. Stomach from 86 specimens (230-354 mm) having a sex ratio 1M : 2.2F were examined. Among 86 specimens, 19 stomachs were empty.

The contents were invariably in a crushed and semi-digested condition, being helped in this process by the vomerine, palatine, and sphenoid denticles. A variety of food organisms were encountered in the stomachs but the main constituents were insects, fishes, prawns and plant matter. The average percentage composition of the feed is given below :

Plant tissue	- 5.0%	Digested organic matter	- 25.3%
Prawns	- 5.5%	Pebbles	- 4.7%
Insects	- 43.7%	Miscellaneous	- 1.3%
Fish & fish remains	- 14.5%		

Ecological aspects, correlated food and feeding in *Puntius* spp. :

The presence of large quantities of semi-decayed, decayed and digested organic matter together with considerable quantities of sand and mud and crushed molluscan shell pieces show that *P. kolus* feeds mainly at the bottom. The diversity in feeding is due to the great changes that take place in the composition of food organisms in the reservoir and their availability from season to season.

The species spawns in the reservoir and has a prolonged breeding period, individuals of the species spawning almost throughout the year. The seasonal changes in levels of water in the reservoir offer one or other type of food to the fish at all levels and seasons. When water level rises, it inundates parts of decidous bushy areas (Vyasankere) and surrounding cultivable lands around the reservoir, which show a dense grassy vegetation. The decay and mineralisation of this vegetation under submersion forms considerable decaying mass of food which is readily available to this fish as also P. dobsonii as grasses and their seeds are consumed by these fishes freely. Another source of food is the decaying wood, either submerged or brought in during the floods which harbours a large number of insects and their larvae. In addition terrestrial insects also formed an important source of food.

P. kolus is thus not very selective in its feeding and consumes whatever food items are available (euryphagic). The frequent occurrence of ostracods as an item of food indicates that the fish browzes in gradually sloping shallower margins of the reservoir. Among the food items insects (chiefly chironomids), ostracods, gastropods and bivalves form the 'basic food! Bacillariophyceae, Chlorophyceae and copepods, found in smaller amounts, form the 'secondary food'. Some miscellaneous food items like Oscillatoria, Anabaena, cladocerans or annelids that rarely enter the guts, form the 'incidental food'. During post-monsoon months, when the reservoir reaches its maximum level as a result of the floods inundating the cultivable and shallow grassy lands, the water becomes turbid and larger animals scarce the fish perhaps is then forced to consume enormous quantities of grass seeds and other vegetable matter. These form the 'obligatory food' until the basic food springs up in the littoral regions.

Since this fish browses at the bottom, large quantities of sand particles and mud also enter the guts. The detritus taken directly or indirectly is presumed to have bacteria and particulate organic matter, which are involved in the breaking up processess of the decaying matter. Detritus itself may form a not inconsiderable part of food.

P. dobsoni was observed to be a voracious, littoral, submerged and emergent vegetative feeder. 'Secondary food' items such as the gastropods are taken in the absence of 'basic' vegetative food. The fluctuations in the density of littoral vegetation, influenced by the increase or decrease of water level of the reservoir, are very closely reflected in the food items of the fish.

Changing water levels of the reservoir acts as a factor in controlling aquatic vegetation which is utilised by the fishes like *P. dobsoni*, *P. pulchellus* and *P. sarana* as their 'basic' food. In the absence of this food, the forms have to migrate or seek food in other zones or adopt to 'obligatory' foods present in the area. The right wing of the reservoir (Vyasankere), which is one of the deepest portions and known for its richness of molluscan fauna supports very little littoral vegetation, the bed being almost gravelly and rocky. This was reflected in the higher percentage composition of gastropods in the feed of *P. dobsoni* in April (21.0%) and May (45.0%) caught in the vicinity of Vyasankere.

Occurrence of a high percentage of ciliates between September (3.8%) to March (6.6%) finds a parallel in the relative richness of vegetion which provides the necessary shade and shelter. Algal and associate forms (diatoms) and planktonic crustaceans were also encountered in the feed of *P. dobsoni*.

Hence it is noted that a strong relationship exists between the water level of the reservoir and available submerged vegetation, which are again closely correlated with the feed of this fish.

Catfishes :

1. *Mystus seenghala*

M. seenghala was the predominant major catfish of the reservoir forming 36.4 and 24.22% of the total commercial fishery during 1964 and 1965 respectively. Stomachs from 141 specimens (309-1010 mm) with a sex ratio of 1.3M : 1F were examined for food, of which 95 were empty. The most dominant food item was fish and fish remains (96.1%), followed by prawns (1.2%), insects (0.3%), sand particles (2.2%) and digested matter (0.2%).

2. *Mystus aor*

This species formed the second and third dominant fishery among catfish population, accounting for 11.08 and 10.70% of the total fishery during 1964 and 1965 respectively. In all 138 specimens (331 to 815 mm) with sex ratio of 1M : 1.8F were examined, of which 86 stomachs were empty. This species is also predominantly a fish feeder as revealed by the stomach contents :

Plant tissue	2.1%	Fish and fish remains	49.9%
Gastropods	0.5%	Animal matter	7.1%
Prawn remains	19.3%	Digested organic matter	8.0%
Insect remains	13.1%		

3. Wallago attu

The species formed the third and second dominant fishery amongst the catfishes and in the commercial fishery accounting respectively for 8.14 and 11.50% during 1964 and 1965. Stomachs from 133 specimens (209-795 mm) with sex ratio 1M : 1.7F were examined, of which 99 were empty. The gut contents were similar to that of other major catfishes, where forage fish formed the most dominant item of food upto 95.9%. The percentage of various items is given below :

Insects	2.8%	Animal matter	1.0%
Fish and fish remains	95.9%	Decayed organic matter	0.3%

4. Silonia childrenii

This is an important catfish of the Tungabhadra reservoir and peculiar to it, occuring throughout the year forming the fourth major fishery among catfishes. 280 specimens (231 to 625 mm) were examined, of which 118 were empty. This fish showed a sex ratio of 1M : 4.3F. The average percentage composition of the feed is as follows :

Prawns	3.4%	Animal matter	13.8%
Insects	9.1%	Decayed organic matter	1.1%
Fish remains	72.6%		

5. Pseudeutropius taakree

Although P. taakree contributes greatly to the commercial catches by numbers as compared to the other species but its fishery is not of much importance as the total production is low, the fish being small-sized. Only 68 specimens (135-415 mm) were examined, of which 16 had empty stomachs. Sex ratio was 1M : 3.5F. The percentage composition of the feed is given below :

Crustaceans	8.7%	Animal matter	9.4%
Insect matter	54.5%	Decayed organic matter	8.4%
Bivalves	0.2%	Mud	0.8%
Fish remains	18.0%		

6. Mystus cavasius

35 specimens (132-350 mm) were examined, of which 7 had empty stomachs. The following percentages of feed were found :

Vegetable matter	2.1%	Animal matter	9.3%
Crustaceans	4.1%	Decayed organic matter	21.8%
Insects	12.7%	Mud	3.7%
Molluscs	45.4%	Miscellaneous	0.9%

Role of forage fishes in the diet of catfishes :

The catfish population of the reservoir preyed upon the abundant 'weed' or 'trash' fishes like Puntius sophore, P. ticto, P. amphibius, Aspidoparia morar, Oxygaster spp, Rasbora daniconius, Chela atpar, Glossogobius giuris, Osteobrama spp., etc. Forage fish concentration, as already indicated earlier, was seen in the shallow, littoral areas especially in zones II and III. Sovinahalli-Hampasagar stretch and Katharki-Tambrahalli Bays as well as numerous shallow inundations and inlets from Mudalighatti to Muttukur offered sufficient submerged and emergent vegetation (Chara, Vallisneria, Hydrilla, Spirogyra and other algal blankets) as cover and food for the forage fishes from September to January. The Riverine and Admixture zones, with the fall in water land between February-March to June, confine themselves to the old river bed, varying in depth from 1-2 metres where the forage fishes become concentrated along with the predators.

M. seenghala was observed generally to prey upon Oxygaster spp. (33 to 70 mm), Puntius sarana (125 mm), P. kolus (114 mm), Osteobrama spp. (134 mm), Glassogobius giuris (85-127 mm) and even Mystus cavasius (113 mm). Though fish formed the basic food

(49.9%) of M. aor, the species was also found to feed upon prawns (19.3%), insects (13.1%) and others. Oxygaster, Chela, Barilius, Aspidoparia, Mystus cavasius, Ompok bimaculatus and Rita spp., (33 to 120 mm), formed the food of this fish.

Wallago attu was found to subsist mainly on young fish (95.9%). Oxygaster spp., Puntius sophore, C. reba, Ompok spp., Rita spp., and G. giuris, ranging in length from 38 to 131 mm, were found to have extensively entered its diet.

Silonia childrenii was found to prey upon young fishes (72.6%).

Both P. taakree and M. cavasius accounted for about 18.0% of young fish in their diet. As both these species feed on insects and molluscs they were not entirely dependent upon young fishes. O. vigorsii and N. notopterus, found in large numbers, also consume fishes. Though, however, murrels and Mastocembelus are also fish feeders, their numbers are negligible.

There are certain areas (isolated inundable portions) where young Puntius spp. or Cirrhina reba occur. Their availability indicates their extensive breeding and repopulation capacity year by year. Good numbers of other species are recruited annually through the monsoon floods (ref : chapter on Recruitment) and they may form, while still in larval or fry stages, considerable food for the catfish young (fry and fingerlings) which are brought into the reservoir from the river.

Correlation of biota and plankton with feeding habits of fishes :

Littoral and Bottom Biota

Bottom biota constitutes an important link in the food chain of fishes in inland water sheets, particularly in tanks and reservoirs where distribution of bottom organisms is a function of environmental conditions.

P. kolus

P. kolus is a confirmed bottom feeder, feeding mostly upon insects (12.5%) particularly chironomids, mayfly nymphs, gastropods including Vivipara spp. and Gyraulus spp. Of the two items, molluscs (gastropods) 76.4% and insects 20.0% available in the bottom biota in January, P. kolus appears to have utilised insects far better than molluscs which formed 19.7% and 17.2% respectively of the total food of the month. Similarly in April, the biota consisted mainly of insects (57.3%), chiefly contributed by chironomids, which were found to an extent of 20.4% in P. kolus followed by molluscs (35.5%) which accounted for 39.8% of the bottom biota. In the second year's December peak, while there was a slight predominance of molluscs (43.9%) over insects (41.7%), the feed revealed a better utilisation of insects (20.1%) over molluscs (9.5%). In May '65, gastropod molluscs (86.8%) greatly predominated over insects (8.0%) in the bottom biota and constituted 31.0 and 7.8% respectively of the food of P. kolus. In September '65, though molluscs (72.7%, mainly gastropods) and insects (15.5%) predominated in the biota, food ingested showed a low utilisation of both (molluscs, 6.9% and insects, 3.8%).

P. dobsoni

During summer months of April and May, there was a predominance of molluscs (87.0%) in Zone IV but the feed of P. dobsoni comprised gastropods only to the extent of 45.0%. Insects (3.5%) and worms (9.4%) of this zone in that month were not utilised by the fish.

Though P. dobsoni is mainly a vascular plant feeder, there is a corresponding relationship between such feed and its availability in each zone. Some of the diatoms which are epiphytic on these submerged vegetation formed an incidental food of the fish, and gastropods formed on obligatory food during low water levels.

Similar trends were noticed in case of P. sarana, i.e. abundance of vegetation and its utilisation by the fish (Vallisneria 4.8-32.5%, Chara 9.1-52.5%, Hydrilla 1.3-23.7%). Further a degree of correlation was observed with the availability of gastropods in deeper zones during summer months and its maximum consumption (11.72-85.0%) as an obligatory food.

P. pulchellus

This fish recorded in Zone III in May of the second year showed 32.8% gastropods in its feed while they were available in the biota to an extent of 89.1%. Bivalves (8.6%), insects (1.2%) and worms (1.1%) present in the biota were not utilised.

Tor spp.

Gastropods dominated the food of *Tor* spp. in general in all the months of observation. During November, the gastropods were fully utilised while insects forming 13.2% and bivalves forming 40.2% of the biota were utilised to an extent of 11.4 and 10.0% respectively. During March, the insects forming 36.8% of biota were fully utilised while molluscs which formed 41.3% and worms forming 21.9% of the biota were left unutilised. However, during April the molluscan (75.3%) dominated biota was fully utilised leaving insects (21.5%) and worms (3.2%) unutilised.

L. fimbriatus

The insect predominance in Zone III (Centre D) especially of chironomids was reflected to the same high proportion in the month of April '64 when it formed 94.0% of bottom biota.

Plankton :

P. kolus

Among planktonic items ingested by *P. kolus*, the dominant groups in order of abundance were diatoms, ostracods, copepods and Chlorophyceae. Diatoms which were the second (20.9%) predominant of the total plankton population of the first year formed 4.6% of the feed of *P. kolus*, copepods and Chlorophyceae forming 21.4 and 10.3% respectively of the total plankton content of the reservoir were found only to an extent of 2.5% and 0.6% in the feed. As the plankton revealed variation in densities of various groups in different zones, the feed of *P. kolus* also reflected related trends.

P. sarana

The available plankton in the month of July showed 28.6% of diatoms in the total plankton which was found to form only 11.5% of the total food. Myxophyceae and Chlorophyceae which formed the rest of the plankton were left unutilised. Similarly in September '64, only diatoms forming 19.1% of the plankton were utilised by the fish to the extent of 16.2%. During January and

February, '65 when available Chlorophyceae was 30.6 and 9.0%, it was found to form 27.5 and 8.2% of the total food in these two months. Chlorophyceae forming 78.5% of the plankton in December, was present only to an extent of 15.0% of the total feed.

L. fimbriatus

The density of plankton population in Zone I, with reference to the food of L. fimbriatus, showed that in December, diatoms were better utilised than Chlorophyceae, in spite of their abundance. While plankton population showed in order of abundance, Chlorophyceae (65.8%), Diatomaceae (24.4%) and Myxophyceae (9.8%) in this zone in December, the food of L. fimbriatus in the same period showed Chlorophyceae (20.0%), Diatomaceae (20.0%) and Myxophyceae (5.0%). In Zone II during September and November, diatoms were fully utilised as food. Myxophyceae (82.3% of total plankton) formed only 2.5% in the total feed. In December, Diatomaceae were fully utilised and Chlorophyceae (72.7%) and Myxophyceae (7.8%) were each found to an extent of 5.0% in the total feed of that month.

In Zone III, the maximum density of Diatomaceae (79.3%), noted amongst the plankton population during January was reflected in the feed of L. fimbriatus, forming 50.0% of the total food. Among zooplankters, copepods constituting 2.9% of the total population in January '65 in this zone formed 1.6% of the total feed. In Zone IV also, when the diatoms formed 47.7% of the total plankton in January, they were found to an extent of 20.0% of the total food during the same period. In August, when diatoms were dominant in this zone, they formed 34.0% of the total food of the month.

BREEDING AND RECRUITMENT

Maturity and breeding of fishes :

The various stages of maturity were recognised by gross examination of gonads of almost all species encountered in the experimental catches, supplemented by specimens from the commercial catches. Seven stages, as adopted by the 'International Council for the Exploration of the Sea', were recognised as 'immature' (I stage), 'maturing' (II stage), 'mature' (III, IV and V stages), 'spawning' (VI stage) and 'spent' (VII stage).

P. kolus

Mature specimens of this species extensively appear in the catches from the reservoir during July to January, though stray mature specimens are caught almost throughout the year. Specimens with immature gonads are more frequent in the first half of the year, with maturing, mature and spawning stages occuring towards the latter half of the year. This species has a prolonged breeding season with two peak breeding seasons, the first peak being in July-August and the second in November-December. Stray specimens with spent gonads are encountered in the first half of the year when majority of carps do not spawn. Unfavourable, low water level conditions in the reservoir probably discourage its breeding even though mature specimens are ready to spawn at the time. Extended breeding, though peculiar to the species, the individuals spawn only during high water levels. Hence, breeders are scarce within the reservoir during summer months. Since number of spent gonads recorded were high in August-September, it was concluded that majority of the individuals breed during July-August. Though a river form, P. kolus is adopted to breed within the lacustrine conditions. It does not require migration to the upper reaches for spawning.

P. sarana

Maturing and mature specimens are recorded in the catches during January-May. A large percentage of fish with mature and spawning stages of gonads were noticed in March-April, thereby indicating the approach of the breeding season. Even with moderate rains the species spawns in May. In July, oozing and milting specimens were available in the commercial catches from inundated bays in very large numbers. From the above, it is established that this fish can spawn in May-June itself in the reservoir but mainly in July depending upon rains and floods. It is also acclimatised to spawn in the lacustrine environment.

P. dobsoni

Among the few gonads collected from specimens in the gill net catches, maturing gonads were encountered in the month of July indicating that this fish breeds only during monsoon. It migrates to the river above the reservoir. Gonads found in some specimens in spent and absorbent conditions during August-September can be attributed to the abnormally late onset of the south-west monsoon in 1965. The occurrence of fry and fingerlings (23 to 67 mm) in abundance during October-November in inundated margins, further supports that the species breeds during July-August.

L. fimbriatus

The few records of maturing and mature gonads in summer months and in oozing condition in Zone I during the monsoon months supports the view that this fish also breeds in July-August in the river above. The negligible fishery of the species, and poor availability of the fry and fingerlings show that the species is not of appreciable value in the reservoir and does not spawn in it.

O. vigorsii

Maturing and mature gonads of O. vigorsii were found in the catches from February to October, a peak in its gravid condition occurring in May-June. As small numbers of mature specimens were also recorded from February to October, it can be concluded that the species has a prolonged breeding season, the younger ones breeding earlier even in moderate rains and floods. The young of the year ranging in length from 15 to 50 mm were collected from June-July confirming its breeding during May-June, i.e. early monsoon inflow. The species thus breeds both during monsoon and post-monsoon months extending up to October-November in the lacustrine conditions and also in the riverine conditions as evidenced by the migrating gravid fishes and young encountered with the influx of flood water during monsoon, at Centres A and B (Zone I and II). Fry and small-sized fingerlings were obtained in September-October.

N. notopterus

This species is found to have a single peak breeding season during the monsoon months. Though specimens with maturing gonads were encountered during the summer months, ripe and gravid specimens were noticed only during monsoon months. Fingerlings (37-46 mm) were recorded in November.

M. seenghala

Few specimens with gonads in III, IV and V stages of maturity were encountered during March-April, mainly in the upper reaches of the reservoir. At no time fully gravid specimens were encountered in catches (both commercial and experimental) within the reservoir indicating that mature individuals leave the lacustrine environment in February-March-April and migrate to the river above for breeding. With the observations made and availability of stray juveniles in the month of September of about 77 mm, it is established that this fish breeds well before the onset of monsoon in the river above. A large number of fingerlings are brought into the reservoir in July-August during floods from the main river, causing recruitment of young from the river stretches above.

M. aor

The gonads were found to be in maturing and mature stages in the months of February, March and April. From the collections of a good number of young fishes (31-72 mm) as associates during spawn exploration work in the upper reaches of the reservoir in June-July, it can be said that M. aor with its premonsoon breeding also leaves the reservoir and migrates to the main river above. M. aor, however, is a frequently occuring commercial species in the reservoir. However, none of the two (M. seenghala and M. aor) species spawns within the reservoir.

W. attu

The gonad conditions of W. attu revealed maturing, mature and spawning stages during the months of June, July and August, the last stage only at Mudalighatti (Centre A). The species breeds during monsoon in the river which is substantiated by the occurrence of juveniles (56 to 126 mm) in September 1964 and 1965 in the river. It does not breed within the reservoir and young are recruited in great numbers from the river stretch above, as observed during spawn collection operations.

S. childrenii

Maturing and mature specimens were observed towards the end of April and in May-June. At no time ripe or gravid specimens were encountered. Juveniles (99-121 mm) collected from the river and a few adult specimens caught during experimental fishing in May and June in III and IV stages of maturity indicated that this fish migrates to the river proper for breeding.

P. taakree

P. taakree is also a monsoon breeder, migrating up the river for breeding as confirmed by the gonad examination of specimens caught during experimental fishing.

Maturing and mature specimens were recorded in April-May in the reservoir and stray specimens showing gonads in fully ripe conditions were observed during the post-monsoon months only at Centre A. Undoubtedly it breeds during July-August as supported by the occurrence of fingerling (26 to 54 mm) in the month of September. Juvenile *P. taakree* of 0 + and 0 + 1 age groups were recorded in large numbers in shore seine catches ('alivi') during summer months, indicating that the fish had bred in the previous monsoon season and young were brought by the river colonising later the reservoir area.

Fecundity

The fecundity of some of the species are tabulated below :

Species	Size ranges		No. of ova	
	Minimum	Maximum	Minimum	Maximum
Puntius kolus	263	460	1,415	9,755
Puntius sarana	244	256	8,376	57,387
Osteobrama vigorsii	322	325	4,772	95,370
Silonia childrenii	455	533	10,012	1,94,398
Rita pavimentata	325	340	13,660	44,790

Spawning

Observations directed towards location of spawning grounds spawn occurrence and self-recruitment capacity of various fish species in the reservoir were undertaken during the years 1964 and 1965. Gangetic major carps, introduced in the reservoir did not breed within the reservoir as at no time eggs, larvae or fry were recorded. Occurrence of *Catla* fingerlings in the post-monsoon months indicated likely breeding of this form for the first time in 1966. Though some large-sized *C. catla* (904-1010 mm), *L. rohita* (855 mm) and *C. mrigala* (only immature ones) were recorded before the monsoons, the specimens were found either egg-bound or fully mature and never in the oozing or milting condition. During the two years' study, the eggs and hatchlings collected during monsoon floods, on rearing proved to be those of L. fimbriatus, L. calbasu, L. porcellus, L. potail, L. bata and C. reba to the exclusion of other carps. The quality and quantity of eggs and larvae, number per net/hour and their species composition (as determined by rearing) during the two years of observations are given in Table 12.

Table 12

Quality and quantity of eggs/spawn as recorded on peak days of collection during 1964 and 1965.

Date	Quantity egg/spawn	Peak hours of catches	Catch per net per hr.	Species composition(%)	
1	2	3	4	5	
27.5.64	60,000 eggs	10 AM-2 PM	75000	Ompok bimaculatus M. cavasius	99% 1%
6.6.64	7,000 eggs	10.30 AM-2.30 PM	583	C. reba L. fimbriatus L. porcellus L. bata Others	71.4% 16.6% 5.9% 3.5% 2.6%
18.6.64	36,000 eggs	10 AM-3 PM	1240	L. porcellus L. fimbriatus Oxygaster spp.	60% 37.1% 2.9%
19.6.64	45,000 eggs	11 AM-3 PM	2250	P. taakree C. reba L. porcellus Oxygaster spp.	43.7% 28.3% 21.6% 6.4%
30.6.64	7,500 eggs	10 AM-3 PM	250	L. fimbriatus L. porcellus	51.4% 48.6%
4.7.64	7,500 eggs	10 AM-3 PM	300	L. fimbriatus L. porcellus Oxygaster spp.	80.0% 10.0% 10.0%

contd.......

1	2	3	4	5	
5.7.64	20,000 spawn	10 AM-2 PM	1000	L. fimbriatus C. reba	85.7% 14.3%
6.7.64	25,000 spawn	10 AM-3 PM	1000	L. fimbriatus Oxygaster spp.	34.0% 66.0%
18.7.64	450 spawn	10 AM-1 PM	150	L. fimbriatus C. reba	75.0% 25.0%
5.6.65	5,834 eggs	8 AM-10 PM	310	P. taakree(?)	100.0%
20.6.65	3380,000 spawn	17.30 PM-18.33 PM	281690	L. porcellus L. fimbriatus C. reba Miscellaneous	60.0% 5.0% 20.0% 15.0%
21.6.65	62,500	9 AM-15 PM	2500	L. porcellus Puntius spp. Others	65.0% 25.0% 10.0%
16.7.65	1,300	7 AM-8.30 AM	324	L. fimbriatus L. porcellus L. bata C. reba	5.0% 65.0% 5.0% 25.0%

The two years, 1964 and 1965, were poor rainfall years. However, the main days of collection indicated among indigenous carps, only Labeo porcellus and L. fimbriatus and catfish eggs. Spawn of minor carps including C. reba were also obtained.

Post-larvae, fry, juveniles and 'trash' fish :

Occurrence of post-larvae, fry and juveniles was studied from July 1964 to September 1965 to ascertain recruitment of both the commercially important species as well the 'weed' or 'trash' fishes in the reservoir. Species encountered during this survey helped in the determination of approximate periods of breeding and the availability of forage fishes within the reservoir. The data obtainedwere however meagre to predict the fish stocks.

Collections of post-larvae and juveniles was made fortnightly by operating an improvised scoopnet in the shallower areas in the vicinity of all the seven centres. The collections were segregrated and total lengths of various species recorded besides the total numbers of each species (Table 13).

Modalighatti, Sovinahalli, Hampasagar and Tambrahalli were rich as far as post-larvae and juvenile fish occurrence was concerned. Katharki, however, revealed congregation of juveniles in the post-monsoon months, when probably the bay offered ideal surroundings as a nursery. They were in stray members in the comparatively deeper zones of Karkihalli and Vyasankere, and poorly congregated in the Riverine Zones namely Modalighatti and Sovinahalli where food was scarce. Post-larvae and juveniles of catfish occurred in limited numbers. This may be due to their preference for fairly deep areas rather than margins. While weed fishes were available all over the reservoir during a greater part of the year, cat-fish juveniles were limited only to monsoon months in the upper reaches, their breeding being restricted to south-west monsoon months.

<u>Chela atpar</u> :- It can be seen (Table 13) that <u>C. atpar</u> has only a single breeding season extending from May to June/July. This finds support from the availability of juveniles (15-42 mm) in August&their (18-37 mm) greater abundance in September. <u>C. atpar</u> in the riverine stretch above the reservoir revealed gonads in V and VI stages of maturity in the month of June indicating their spawning during monsoon season.

<u>Oxygaster</u> spp. : There are 2-3 species, all of which are prolific breeders, the breeding season starting from May continues up to December. Very few individuals were found breeding during summer months, maximum peak being observed during the monsoon months. This was supported by the abundance of post-larvae and juveniles in that season (cf Table 13).

Table 13.

Species-wise size ranges (in mm) and numbers of juveniles

	July-September			October-December			January-March			April-June			July-September		
	No.	Size		No.	Size		No.	Size		No.	Size		No.	Size	
		Mini.	Max		Mini.	Max.		Mini.	Max.		Mini.	Max.		Mini.	Max.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. N. notopterus	-	-	-	2	37	46	2	61	157	-	-	-	-	-	-
2. C. atpar	68	15	68	41	27	48	5	41	45	6	36	49	272	18	63
3. Oxygaster spp.	435	10	115	1261	12	96	983	20	107	752	7	92	883	11	104
4. B. barila	19	30	70	17	27	44	8	22	25	3	20	35	27	26	48
5. B. barna	12	28	144	-	-	-	13	52	84	6	22	60	127	23	75
6. D. aequipinnatus	-	-	-	-	-	-	7	59	65	-	-	-	-	-	-
7. E. danrica	1	31	-	3	41	44	4	27	51	-	-	-	-	-	-
8. R. daniconius	36	16	68	238	19	75	71	25	82	223	27	66	534	16	66
9. A. morar	278	11	114	931	15	89	266	19	50	1	27		288	12	90
10. Tor spp.	-	-	-	1	70	-	-	-	-	-	-	-	-	-	-
11. P. sarana	8	43	48	21	33	67	-	-	-	1	35		-	-	-
12. P. dobsoni	-	-	-	36	23	67	25	35	87	4	57	58	3	43	82
13. P. chola	1	40		98	13	65	-	-	-	-	-	-	13	26	37
14. P. kolus	11	14	24	13	29	114	2	48	53	18	15	45	-	-	-
15. P. amphibius	7	37	38	1	64		2	42	44	-	-	-	-	-	-
16. P. puckelli (P. dorsalis)	-	-	-	1	67		5	20	37	-	-	-	-	-	-
17. P. ticto	7	14	54	12	15	42	554	13	47	716	20	42	41	15	47
18. P. ambassis	3	22	28	-	-	-	-	-	-	6	-	-	7	27	44
19. P. stigma	298	14	82	440	13	86	55	17	83	61	20	93	230	17	102
20. P. narayani	-	-	-	-	-	-	-	-	-	1	35		-	-	-
21. C. reba	168	14	60	432	15	76	31	18	43	22	8	46	853	13	76
22. Garra spp.	4	27	39	6	17	35	-	-	-	-	-	-	206	17	38
23. L. fimbriatus	13	20	52	5	26	41	-	-	-	-	-	-	31	18	37
24. L. porcellus	14	19	36	139	13	92	22	22	47	3	20	25	1064	13	81

contd.......

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25. L. potail	1	44		3	30	66	3	26	40	1	52		114	24	76
26. L. boggut	15	26	37	-	-	-	-	-	-	-	-	-	-	-	-
27. L. boga	274	17	68	265	27	72	1	45		-	-	-	1002	12	37
28. O. vigorsii	1610	12	129	37	55	108	13	25	72	45	15	110	46	15	95
29. O. neilli	27	14	48	46	15	35	98	22	53	324	19	65	442	12	44
30. O. ogilbii	-	-	-	1	60		-	-	-	-	-	-	2	42	96
31. O. cotio	162	20	84	5	22	47	2	31	35	159	34	84	35	14	45
32. B. dario	2	13	14	-	-	-	-	-	-	1	35		18	12	42
33. N. evezardi	-	-	-	3	36	39	8	25	55	2	41	53	8	22	36
34. O. bimaculatus	8	24	76	66	41	93	-	-	-	1	126		135	37	98
35. W. attu	2	56	126	-	-	-	-	-	-	-	-	-	5	86	116
36. M. aor	-	-	-	-	-	-	-	-	-	85	31	72	-	-	-
37. M. seenghala	2	77	78	-	-	-	-	-	-	-	-	-	-	-	-
38. M. punctatus	3	15	53	-	-	-	-	-	-	-	-	-	-	-	-
39. M. cavasius	5	19	86	2	54	83	-	-	-	53	103	125	-	-	-
40. G. itchkeea	-	-	-	1	27		-	-	-	-	-	-	5	20	30
41. P. taakree	20	25	54	-	-	-	-	-	-	21	44	68	4	45	69
42. X. cancila	-	-	-	-	-	-	-	-	-	1	155		1	42	
43. H. lineatus	-	-	-	3	23	44	13	20	53	1	62		2	31	64
44. C. striatus	-	-	-	2	106	127	-	-	-	-	-	-	-	-	-
45. P. cupanus	-	-	-	15	15	40	25	28	45	1	39		13	14	47
46. A. nama	1	41		1	26		31	27	58	23	12	45	23	37	58
47. A. ranga	474	8	59	88	11	56	137	9	68	208	17	67	124	9	67
48. G. giuris	-	-	-	43	18	55	43	18	200	6	16	30	6	25	37
49. M. armatus	1	81		4	27	101	-	-	-	87	12	31	-	-	-

Barilius barila and B. barna : Juvenile occurrence of Barilus spp. in considerable numbers within the size range of 26-39 and 23-53 mm respectively was recorded in the month of August. Hence these fishes breed during monsoon months. In case of B. barila, breeding takes place even in October-November, during the north-west showers.

Rasobra daniconius : This species has a prolonged breeding season in the reservoir, individuals breeding between May and December generally. Breeding peaks occur in July-August in response to south-west monsoon and again in November-December under the influence of local rains. This was supported by mature gonad conditions in several individuals as well as by the occurrence of juveniles (16-66 mm) in September and specimens ranging in size from 25-27 mm in February-March.

Aspidoparia morar : The post-larvae and juveniles ranging in sizes from 16-33 and 12-37 mm were found in abundance in December 1964 and September 1965, showing the prolonged breeding from May to January but having two peaks in July-August and September-October, the latter being the main peak. Neither post-larvae nor any juveniles were encountered during the summer months.

Puntius chola : From the few juveniles, 13-55 and 26-37 mm, encountered in scoop nets during October '64 and September '65 respectively and their complete disappearence in the collections during January to July, it can be said that this fish breeds in June/July-September.

P. amphibius : This species is not so common in the reservoir as in the river above, from where it is recruited in the reservoir. This form was encountered in large numbers in the Riverine Zone (Centre A). From the few post-larvae collected, it appears to breed during monsoon and post-monsoon seasons only.

P. ticto : This fish was obtained in reservoir pockets (bays) where there was a stabilized water level. The species appears to breed between August and February with a peak in December-January, post-larvae and juveniles in the size ranges between 13 and 37 mm in February, 17 to 47 mm (majority between 17-25 mm) in March and 22-42 mm being available in April 1965 which is a clear indication of its having bred during winter months. The species also spawns in early monsoon showers, but this does not appear to happen in the Tungabhadra reservoir, as its population during summer months is completely decimated.

P. stigma : This fish was seen commonly in bays where there was no flow of water. It was found to breed during monsoon months (in July-August) as supported by the collection of post-larvae and juveniles ranging in size from 17 to 28 mm in September 1965; in a few cases it may even extend upto October depending upon favourable ecological and low water conditions.

C. reba : This species is known to breed between June and September. From the occurrence of post-larval stages and fry in the collections, it seems that *C. reba* is a prolonged breeder between May and December depending on the surrounding conditions (initial showers and less turbid water) with two peaks in June-July and October-November, of which the former being a major peak. Further, stray specimens with gonads in fully ripe (gravid) and spent recovering stages were recorded in the experimental fish catches during December and January. Occurrence of post-larvae (13 to 36 mm) in September 1965 with variation in numbers from zone to zone clearly indicates that the species breeds mainly in June-July.

Garra spp. : The species comprising the genus are more of riverine rather than lacustrine forms. Post-larvae and juveniles ranging from 17-38 mm were collected in September 1965 and appear to have been brought by the river above. The genus was not encountered at other times.

Labeo porcellus : This species breeds during the monsoons which is supported by the availability of gravid specimens in the catches and also the occurrence of juveniles in the post-monsoon months. The species formed a very poor fishery in the reservoir.

L. potail : The occurrence of fry and fingerlings ranging in size from 24 to 53 mm in September shows that this species breeds during the monsoon months.

L. boga : This species also breeds in the months of July-August as evidenced by the availability of fingerlings during post-monsoon months. These were recruited from the river as the species otherwise is absent in the reservoir.

Osteobrama neilli : The species spawns both during the south-west and north-east monsoon seasons.

O. cotio : This fish was found also to breed during monsoon months. It occurs in numbers in the 'alivi' catches.

Botia striatus : This species breeds somewhere in June-July as evidenced by the appearance of post-larvae (13-14 mm) in the collections during August.

Ompok bimaculatus : This species, common in the 'alivi' catches but rarely encountered in gill-nets breeds during June-July as supported by the occurrence of juveniles (37 to 98 mm) in September. Early floods bring huge quantities of its eggs.

Mystus maydelli : This fish appears to spawn during the monsoon months as post-larvae and juvenilies were recorded in July-August.

M. cavasius : The species appears to be a pre-monsoon breeder, as very few juveniles, (19 to 47 mm) were available in August. Yearlings (106-195 mm), however, were collected from the inundated areas of Hesrur in June, 1965. Stomach contents revealed the presence of a large number of carp fry. It forms a major fishery in the 'alivi' operations in shallower waters of the reservoir during the summer months.

Macropodus cupanus : This small fish was occasionally seen in the undisturbed bays. It breeds during south-west monsoon as supported by collections of juveniles (15 to 40 mm) in November.

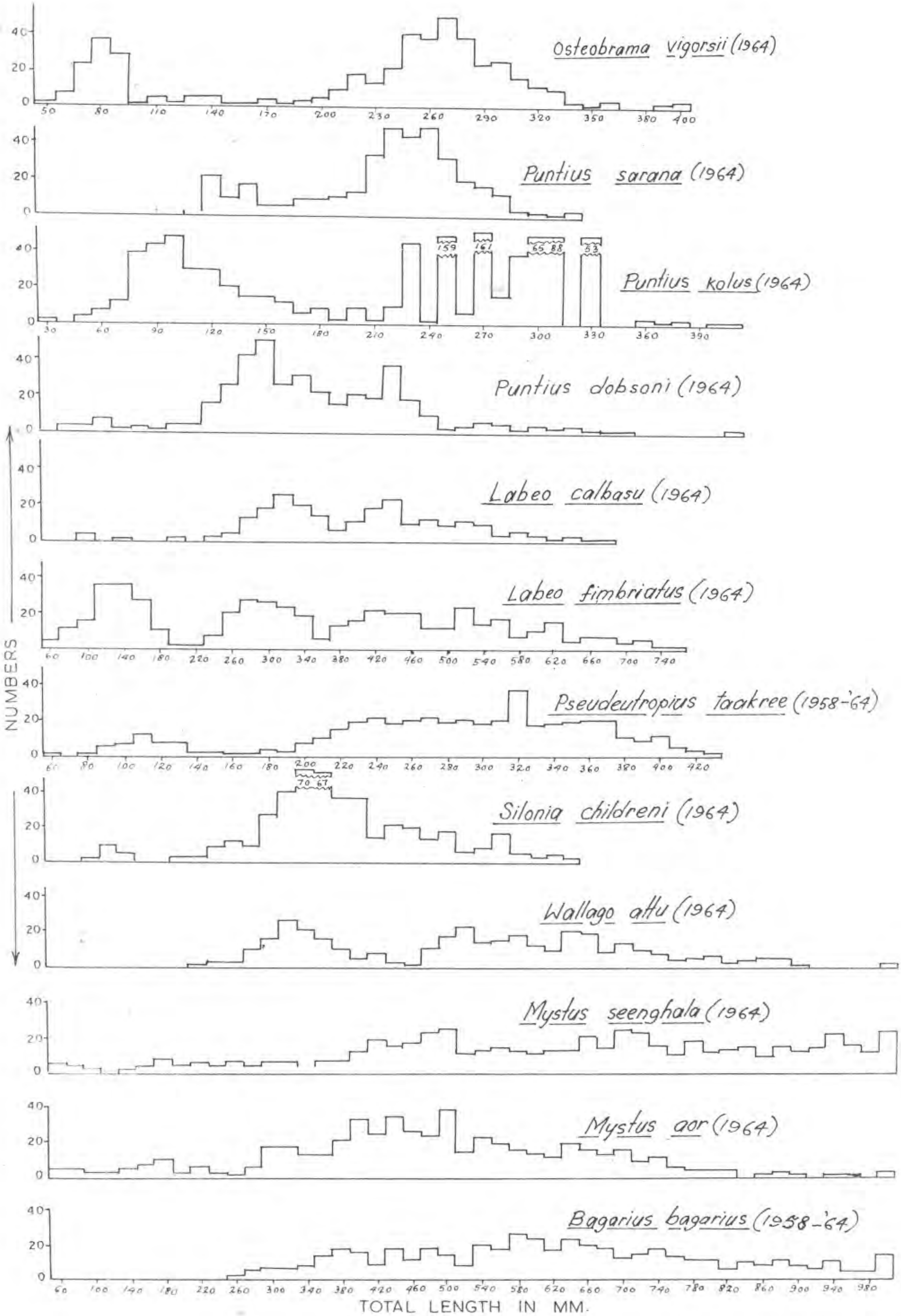
Ambassis ranga : Occurrence of *A. ranga* in 'alivi' and other dragnet operations is common during the summer months. The species breeds during early monsoon and the fry are well-grown by July-August.

Glassogobius giuris : This species appears to be a prolific breeder within the reservoir. Young ones occur during monsoon floods, entering the canal below and colonising fish nurseries interfering with major carp fry production.

Mastocembelus armatus : The species is recruited from the river above and also breeds in inundated bays during May-June. Availability of young ones (10-31 mm) in June 1965 clearly indicated its spawning during May-June within the reservoir bays.

Remarks : The richness in the juvenile fish population within Hampasagar, Tambrahalli and Karkihalli bays is to be attributed to two causes (i) The zones are wide-spread shallower bays situated close to the tail and middle part of the reservoir, possessing rich marginal aquatic vegetation (particularly Tambrahalli) and grass which provide abundant shelter; (ii) these bays offer suitable grounds for protection of post-larvae during flooded conditions and also act as supplementary spawning grounds for smaller species.

Considering the occurrence of juveniles amongst the desirable and trash fishes, it can be seen that weed fish population is highly rich compared to the juvenile fishes of larger, commercial forms. The size ranges and their numbers recorded in various months of the year, provide an idea both as regards their rate of average growth from month to month as also their peak breeding season and the extent of breeding periodicity of the individual species. During these studies, as many as 49 species were recorded. The breeding periodicity and rate of recruitment of weed fishes are not dealt with in detail, but their size ranges and numbers and periodical changes in their abundance provide a fairly accurate picture of the population structure as a whole.



TOTAL LENGTH IN MM.

FIG. 12

LENGTH FREQUENCY DISTRIBUTION OF IMPORTANT CARPS AND CATFISHES IN COMMERCIAL CATCHES.

GROWTH AGE AND OF SOME FISHES OF THE RESERVOIR

The age growth of some fishes were computed on the average length-frequency distribution (Fig.12). Fishes were measured at various landing centrea and Hospet fish market which gave a good representation of the fish population of the Tungabhadra Reservoir. However, this did show some gaps in age groups presumably due to the selectivity of gill nets used by commercial fishermen from time to time. In such cases the 'alivi' catches could furnish adequately the remaining age groups which are now utilised. Observations over several years at Hospet fish market reveal dominance of some locally important size groups. The length increments as computed at present are tentative (Table 14). In general most fishes attained their catchable length in their second and third years.

Table 14.

Age and rate of growth of certain fishes of the Tungbhadra Reservoir

Sl. No.	Species	Year	Average length (mm)	Average weight (kg)	Approx. increment in length (mm)
(1)	(2)	(3)	(4)	(5)	(6)
1.	Puntius dobsonii	I	120	0.029	-
		II	300	0.451	180
		III	460	1.533	160
		IV	580	3.200	120
		V	640	3.701	60
		VI	680	4.928	40
*2.	Puntius kolus	I	100	0.011	-
		II	190	0.185	80
		III	240	0.199	50
		IV	280	0.269	40
		V	320	0.418	40
3.	Puntius sarana	I	138	0.039	-
		II	208	0.150	70
		III	238	0.164	30
		IV	268	0.327	30
		V	238	0.376	15

contd.....

* The age groups may refer only to six monthly growth as the species spawns twice a year.

(1)	(2)	(3)	(4)	(5)	(6)
4.	Labeo fimbriatus	I	140	0.040	-
		II	300	0.321	160
		III	440	0.049	160
		IV	540	1.994	100
		V	640	3.210	100
		VI	700	4.687	60
		VII	740	6.229	40
5.	Labeo calbasu	I	160	0.050	-
		II	320	0.439	160
		III	440	1.326	120
		IV	520	2.021	80
		V	600	2.268	80
		VI	640	3.000	40
6.	Osteobrama vigorsii	I	80	0.055	-
		II	160	0.045	85
		III	220	0.120	160
		IV	270	0.187	50
		V	310	0.306	40
		VI	330	0.305	20
7.	Mystus seenghala	I	220	0.440	-
		II	500	0.642	280
		III	700	1.862	200
		IV	840	3.525	160
		V	940	4.258	80
		VI	1020	5.449	80
		VII	1080	6.574	60
8.	Mystus aor	I	180	0.030	-
		II	320	0.233	140
		III	440	0.466	120
		IV	540	0.791	100
		V	640	1.262	100
		VI	700	1.696	60
		VII	740	2.138	40
		VIII	780	2.230	40
9.	Wallago attu	I	-	-	-
		II	320	0.150	-
		III	540	0.744	220
		IV	640	1.261	100
		V	720	2.064	80
		VI	780	2.395	60
		VII	840	2.500	60
		VIII	880	3.709	40

contd.......

(1)	(2)	(3)	(4)	(5)	(6)
*10.	Bagarius bagarius	I	420	0.950	-
		II	588	2.041	160
		III	680	3.685	100
		IV	760	5.901	100
		V	840	7.866	80
		VI	880	9.080	40
11.	Silonia childrenii	I	140	0.020	-
		II	260	0.123	120
		III	360	0.310	100
		IV	440	0.666	80
		V	500	0.951	60
		VI	560	1.401	60
		VII	620	1.804	60
12.	Pseudeutropius taakree	I	110	0.015	-
		II	220	0.100	110
		III	320	0.280	100
		IV	370	0.330	50
		V	400	0.350	30

*Based on inadequate number of specimens.

PART III

COMMERCIAL FISHERIES

FISHERMEN, FISHING CENTRES AND MARKETS

There was no resident local fishermen population on the river before the formation of the reservoir. Only the itinerant tribal fishermen, killekethas fished the river, moving from one pool to the other. 35 families of these fishermen are now resident at Korlahalli village close to the riverine stretch opposite Centre A. These fishermen subsist on fishing for 8 months of the year. Two or three villagers at Hampasagar and as many at Katharki have taken to gill net (Rangoon net) fishing but only once in a way they operate these nets wing coracles as they are mainly cultivators. Their catches are negligible. Fish captured by Killekethas close to Korlahalli and by others in the riverine stretch is sold in the local villages and seldon marketed outside.

About 80 families of Telugu fishermen annually migrate to the Tungabhadra Reservoir from the coastal belt of Andhra Pradesh i.e. from Vijayawada, Rajahundry or Vizagapatanam. They bring efficient gill and seine nets as well as coracles that are operated in the estuarine and wide sandy mouths of the deltaic Krishna and the Godavary rivers. They stay around the reservoir from three to eight months in an year, moving from one centre to the other with their fishing gear. However, 10 families of Tamil fishermen from Mettur area (Madras State), settled at Kampli village, a few miles below the dam, conduct fishing in both the reservoir as well as the 40 km-stretch of the river below the Dam.

There are nearly 40 villages around the reservoir where the above fishermen are active sometime or the other. These can be called 'fishing' centres, as fishermen stay close to the above villages drawing their supplies and disposing their fish to agents of fish traders. These centres commencing from the Dam site on the right flank back to the Dam site are as follows :

Right Flank	Left Flank
Dam site at Tungabhadra Dam	Shingatalur
Vyasankere	Korlahalli
Venkatapur	Kakkur
Narayanadevarkere	Hesrur
Uppanayakanahalli	Nelavagi
Ankasamudram	Bairapur
Anandadevanahalli	Bachenahalli
Bachigondanahalli	Tigiri
Tambrahalli	Hanukunti
Muthukur	Akkapur
Rameswarabandi	Mathur
Siganahalli	Niralgi
Bannigola	Katharki
Enigibasapur	Gondabal
Hampsagar	Mudhaballi
Hakkandi	Hyati
Muddalapur	Mundargi (village)
Sovinahalli	Lachenkere
Mudalighatti	Karkihalli
Nowli	Chikaboganhalli
	Kasankandi
	Damsite on Munirabad

The parties engaged in fishing move from one centre to the other along the reservoirs periphery of 387 km. While during high flood levels from September to December, the fishing units remain scattered in all the far flung centres in the four zones, from January, the seine net fishermen first concentrate close to Zone I (Centre A), and gradually move downwards with the lowering of water level. By April-May, they are found only between Muthukur and Bannigola and between Mathur and Hyati on the opposite side. Gill net fishermen move from one village to the other during summer mainly in Zone IV as gill nets cannot be operated in the 'alivi' fishing areas of the near riverine shallow conditions. (Sketch maps 2 & 3).

Majority of the above villages are situated from 2-8 km from the actual fishing areas during summer. Hence, the fishermen who camp on the river bank depend solely for the disposal of their catches on the fish traders, who send their agents for collecting the fish. However the left flank, except at Hesrur, is not reached by road. On the other hand, though Katharki and Gondabal are connected with roads, these centres are some 8 to 12 km away from the fishing centres and the Katharki Bay thus remains largely unexploited. Hence, catches on the left bank between Katharki and Karkihalli get diverted to Koppal, while from Kasankandi the fish is brought by cycles to Hospet. On account of poor transport facilities, few fishing units camp along the left periphery of the reservoir.

It is found that between 70-75% of the total catch is accounted for at Hospet, nearby $\frac{1}{3}$ of the catch being exported from the left flank centres. About 15% of the catch is consumed locally at Hospet.

The total catch during 1965-66 was estimated to be 2, 43, 624 kg valued at Rs. 97,000/-. But fish traders and merchants make a profit of 200 to 300% of the face value. At least a total amount of Rs. 1,21,812=00 calculated at 0.50 paise per kg is the value of fish produced in the reservoir which could be realised by a co-operative society with minimum profit and handling charges saving to the consumer a high cost once the fish merchants and their agents are eliminated.

CRAFT AND GEAR

There are no fishing boats in the reservoir. Fishermen from Andhra Pradesh and Madras States employ coracles which, being light and cheap are adapted to reservoir conditions. These circular, hide-bound bamboo frames are not only used for transport of families and gear, but also used as shelters. Fishing by gill nets, seines (alivi) and hook and line is carried out with the help of coracles only.

The killekethas use dried water gourds (Lagenia <u>valgaris</u> "bottle" gourds) and small empty sealed tins as floats for treading water while fishing. By their very nature such operations are restricted close to the shores.

Gill Nets:

'Rangoon' Nets : Gill nets generally known as 'Rangoon' nets are employed for surface or sub-surface fishing. These nets, however, are not used as drift nets (as originally intended) but are anchored as wall nets about a meter below the surface. The nets vary from 80-100 m in length and 5-7 m in depth, and are made of nylon twine, with varying mesh sizes ranging from 45 to 90 mm (bar). When of larger mesh (90 to 150 mm bar), they are known as 'Catla' nets, as larger fishes like *Catla* are captured by them.

These nets are operated almost throughout the year, but Zones II and III are exploited extensively by these surface gill nets. Inundated bays and main reservoir region in Zone IV also are fished by these nets where water is sufficiently deep. There are no sinkers on the Rangoon nets, but floats only are strung along the head rope. Though hanging ratio was haphazard in earlier year, recently fishermen have started modifying the nets 50:50 ratio in hanging, and some also use light sinkers to keep the net stable with significantly higher yield per net.

Uduvalai :

Bottom-set gill nets, 70 to 90 m in length and with meshes ranging from 35-80 mm, but widths of only 0.50 to 0.75 m are known as 'Uduvala'. Shallower littoral and the deeper reservoir areas are subjected to fishing by Uduvala. In contrast to Rangood nets, Uduvalas are weighted with small sinkers and are provided with very light, thin reed floats. The net stands up-right on the bottom forming a wall along the contour of the bed. These nets are generally not used in the riverine part except by Killekethas, who are very adept in operating river pools by employing Udavalas. There is a variation of this net known as 'Pedda Uduvala' which possesses advantages of both Rangoon nets and Uduvala, as it is a wider Uduvalas (about 1.5 to 1.75 m in height), with increased surface area.

Almost all the fish species, especially the major catfishes and major medium carps are caught by the above nets in the reservoir.

Drag Nets :

"Alivi Nets : The Tungabhadra reservoir is perhaps the only reservoir in India where shore seines are employed effectively for commercial catches. The surface gill nets are found to catch only between 1.90 - 22.4 kg of fish per net (2 men with 500 m long nets) during the various months. This quantity is uneconomical during major part of the year, considering the effort and low prices prevailing for fish. From 1964, the Telugu fishermen brought an effective shore seine known to them as 'alivi' for large scale exploitation. The net is known as "Pedda Alivi" in Andhra Pradesh. Its structure and design are shown in Fig. 10.

The alivi is an encircling beach seine and is generally a 76 to 100 m long oval piece of net with widths ranging from 3½ m at the two outer edges to 6½ m in the middle. The net hence shows a central bulge which gradually decreases towards the outer edges. The two tapering edges act as wings with the meshes gradually decreasing in size from 25 mm (bar) to 20 and 12 mm on sides but to as small as 7 mm in the exact middle for a length of 45 m. These measurements refer to an alivi of approximately 100 m in total length. This middle portion acts as an effective seive. Cotton twines of 5 to 8 counts are used variously in the making of the net as nylon twines are subject to abrasion. There are selvedeges of 40 mm (2 meshes), and 14 mm for a width of 0.5 m on the bottom from one edge to the other. 3.5 cm thick coir ropes are tied as head and foot ropes and continued on the outer side as a single rope for 100 m on both sides. The head rope is provided with 70-75 wooden floats of 29 to 35 cm lengths and 7 to 9 cm thickness at intervals of 0.75 to 1.75 m. These floats are made up of light wood called "pilukata" (Tellachettu eru = root of white tree) in Andhra Pradesh. No sinkers are ever used. The whole net is tanned as needed using 'tummachakka' bark exatracts.

The operation of 'alivi' nets is restricted to periods of lower water conditions from about January-February to end of May or early June. In Table 15, the water levels in the reservoir, number of alivi nets under operation during different months are presented. During higher levels of 1625-30, the inundable portions usually include shrubby cultivated lands, but as the water recedes, open, soft oozy bottoms offer ideal conditions. In Sketch Map 3,

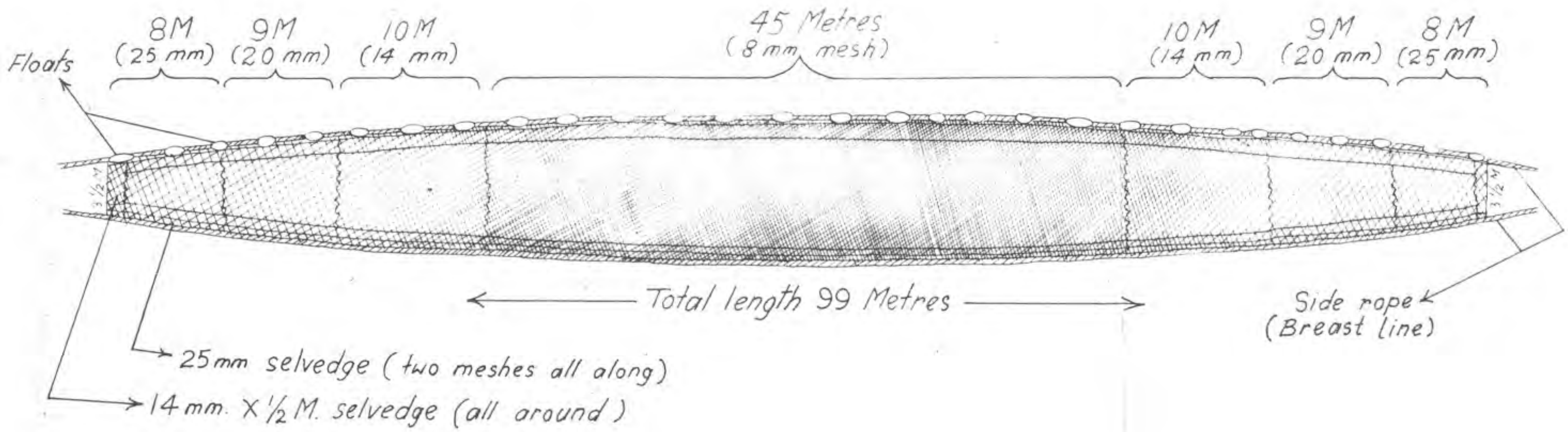


FIG. 10

DIAGRAMMATIC SKETCH OF "ALIVI"
(SCALE :- 1CM = 3M APPROX.)

the various areas served by the shore seines are indicated. The main river stream and adjoining inundated back-wash areas of the reservoir from centre A up to centre B are first subjected to fishing. Silt bar formations in these centres also offer main stream fishing from the middle of the river bed. The outer marginal areas of the reservoir that form depressions and inundations are thus fished first as they offer wide scope for fishing when they are about 3 to 6 m in depth. Where water levels are 1 to $1\frac{1}{2}$ m in depth, alivi operations cease to exist due to unprofitable catches.

Two coracles and six to eight men are usually required to operate one alivi. The nets are operated at all hours but especially from midnight to early morning to enable fish despatches before 7.30-8.00 A.M. On local bazar days, nets are operated even during day time. On the left flank, in the riverine conditions prevailing during April-May (1595 ft levels), alivi operations are held from morning till noon to facilitate despatch to Koppal. In May, as catches increase, even 12 hauls are made by each unit.

A bamboo pole is tied on the two outer edges for rigidity and ropes tied for 100 m or so in length outwards from each edge, lengthening the operational range of one alivi to 300 m. One end being held on the bank, the net is paid into the water gradually from a coracle encircling part of the river or bay. The semi-circular area covered with ropes for 100 m at each end and the net which itself is 100 m, thus encircles a length of 300 m (or 1.4 ha area) semi-circularly when gradually hauled to the shore. One coracle is kept at the middle of the net to disentangle the net and guide it properly. The catch is gradually confined to the smaller meshed middle part and gathered together at the centre on the shore. The large fish are picked up and smaller ones that are hauled with ooze and mud, are first washed, and emptied into the coracle. Five to seven hauls are usually made in a day by an alivi unit, each haul taking about an hour for completion. The fish are sorted and taken by coracle to the assembly centre. The entire operation of alivi is first of encircling, partially scaring fish by outer ropes to the middle and finally effective seiving. No fish can escape once the main part of the net encircles an area making an assessment of the standing crop in the zonal areas possible by studying the captured forms. Larger creeks and bays are covered by several alivi units being brought together and tying 3 to 5 nets.

Year, species wise composition and weights referring to alivi catches are presented in table 16 and discussed further.

Table 15

Estimated total catch (in kg) standard unit-effort and catch per-unit effort (C.P.U.E.) (in kg) for the years 1964 to 66.

Months	Total No. of 'alivi' nets actually examined.	Total weight in examined 'alivi' nets	Average catch per 'alivi' (kg)	* Estimated catch for 20 days in a month(kg)	Reservoir level(in ft.)
1964 :					
February	20	1406.493	70.324	21,097.200	1625
March	60	4697.860	78.297	23,489.100	1620
April	20	1121.219	56.065	16,819.500	1615-1610
May	2	237.134	118.567	35,570.100	1605
				96,975.900	
1965 :					
February	10	322.051	40.256	12,076.800	1625
March	71	6806.248	95.862	28,758.600	1620-1615
April	14	1000.530	71.466	21,439.800	1610-1600
May	12	1533.982	127.831	38,349.300	1595-1590
				1,00,624.500	
1966 :					
January	10	566.000	56.600	27,168.000	1620
February	20	1018.835	50.941	24,451.680	1615
March	8	381.775	47.720	22,905.600	1610-1605
April	5	600.460	120.092	36,027.600	1600
May	9	1104.500	122.722	36,816.600	1595-1590
				1,47,419.480	

* The effort has been made constant and is based upon operation of licenced 'alivis'. For purpose of calculations 20 days of fishing in a month is taken into consideration, as other days are usually spent in moving from place to place or spent by fishermen in waiting for licenses etc. (delays) and so on.

Kuntivala : This is an almost miniature alivi in shape and appearance. Originally meant for prawn and small fishes it is operated in the reservoir by about 30 Telugu fishermen. Its total length is 20-22 m, width from 2½ to 3 m in the centre, tapering on the two outer edges to 1 to 1½ m. Cotton twine is used and meshes are uniformly 10 mm (bar) throughout. Bamboo sticks of 0.75 m are tied at intervals making several pouches in the net during operations. When dragged on the margins the net provides considerable young fish and prawns mainly used as bait for hook and line fishing. Catches otherwise are sundried, only marginal fish being netted during July-August only by this net. The Leander spp., Oxygaster, Aspidoparia, Ambassis sp., etc. are mainly caught by Kuntivala.

Miscellaneous Nets :

Cast Nets : The usual cast (-'throw') nets are used occasionally but mostly they are employed in the river stretch below the Dam. Both types with or without radial cords are used with 10 mm to 35 mm meshes (bar). Almost all poachers use this net below the Dam in the river stretch. They are provided with heavy sinkers for operations in the flowing, rocky areas below. During surplus discharges or soon after, unauthorised fishing below the Dam is mainly seen by employing such cast nets.

A small surface gill net is used by Kellekethas for capturing minnows. A fine meshed 10 mm (bar) cotton twine net (0.5 to 7.75 m wide and 10 to 20 m long) is operated in margins and littoral areas. The net is provided with small reed floats or of broken dried gourds, and mud sinkers. Mainly Oxygaster spp. Puntius spp., Aspidoparia spp., etc., are obtained. Catches are not commercially marketed.

Hook and Line Fishing :

Line fishing with long lines possessing 500 to 1000 hooks are restricted to the months between September and January, to supplement poor gill net catches. With operations of 'alivi', hook and line fishing ceases. Prawns are used mainly as baits and Oxygaster spp, when available. All cat fishes such as Wallago, Silonia, Mystus aor, M. seenghala, M. punctatus, Ompok, Pseudentropius taakree and some carps like Puntius sarana and murrels are caught by these long lines. Areas of operations are confined to Zones II and III, inclusive of Transition Zone from Sovinahalli up to Muthukur, as well as Tambrahalli and Katharki bays.

COMMERCIAL PRODUCTION, COMPOSITION AND TRENDS

Production :

Commercial fish production in the Tungabhadra Reservoir is assessed by :

i) Actual fish assembly data obtained twice to thrice weekly all the year round at Hospet assembly and export centre, and computed monthly.

ii) Estimated 2/3 alivi catches do not come to Hospet but exported from the left flank centres directly to railheads and exported outside between January and June.

iii) 1/3 Gill net catches from July to December escape to the left flank centres

The above trends have been appraised by actual examinations all over the Reservoir once to twice a month during scheduled trips for experimental fishing and biological collections when staff spent 10 to 12 days in the field. Disposition of fishermen, randomised sampling, catch and size composition were hence obtained systematically and computed monthly.

Landings were only 15 to 11 tonnes in 1958 and 1959 respectively; subsequently with licensing, the catch records show an improvement up to 24 tonnes between 1960 and 1962*. A sudden increase in the estimated production of upto 69 tonnes in the year 1963 is due to increased effort by larger number of fishermen and introduction of stray and exploratory 'alivi' nets earlier in summer. Table 17, (fig. 11) presents the catch statistics and composition in percentage by weight of various species for eight years. 1964 recorded a total of 133 tonnes at Hospet and estimated production of 200 t in the entire Reservoir due to extensive 'alivi' operations, which accounted for 97 tonnes between February and May. Similarly in 1965 summer, when water level reached 1590 feet level, the shore seines increased further the total quantity to 156 tonnes at Hospet centre and 235 tonnes in the reservoir of which 101 tonnes were accounted for, by shore seines alone.

* These figures estimated earlier appear to be defective as catch statistics were only partially obtained until 1963 at Hospet Fish Market.

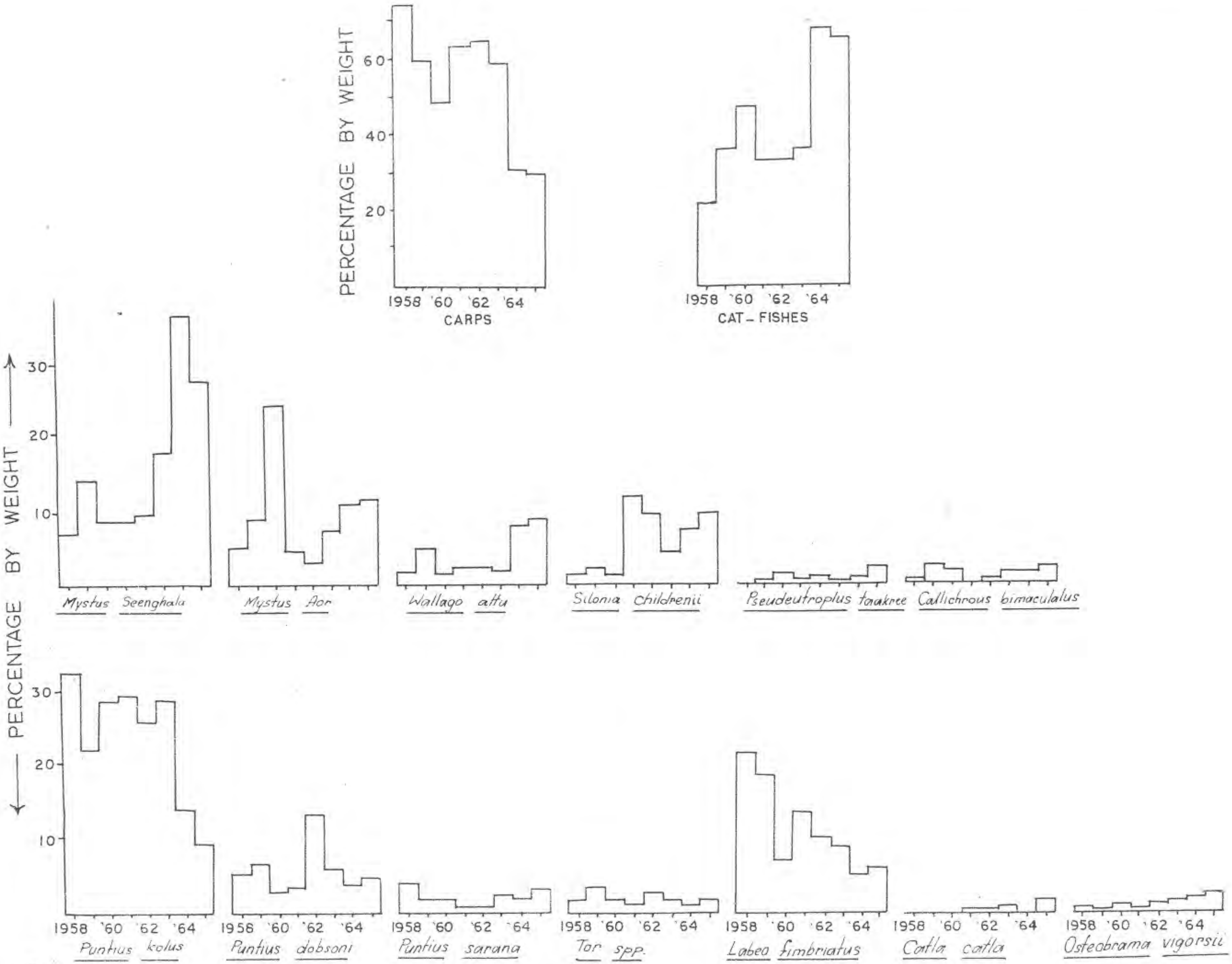


FIG. 11. YEARWISE PERCENTAGE COMPOSITION (BY WEIGHT) OF IMPORTANT CARPS AND CATFISHES IN TOTAL COMMERCIAL CATCHES.

The above estimates are 70 to 75% of the reservoir's total yield, as 25 to 30% of catches do not reach Hospet. From January to June an estimated 2/3 of the catch goes to the left flank towns and only 1/3 of the catch is brought to Hospet centre as the heavier catches cannot easily be brought due to distances for packing. Only 1/3 of the catch is sent to other places and 2/3 comes to Hospet in between the months of July-December as coracle movements and transporation and places of capture facilitate such landings. Towns like Mundargi, Gadag, Hubli, Koppal as well as villages nearby draw away this substantive quantity of fish from fishermen operating the left periphery areas. Hence for all above estimates, 30% has been added. The actual estimated Fish production for the entire reservoir during 1964 and 1965 are as follows :-

	1964 (in kg)	1965 (in kg)
Gill nets	74,114	1,12,313
Hook & Line	10,125	10,125
Shore Seines	96,976	1,00,624
Mixed gears (Gill-Nets Hook & Line, Kuntivala, etc.).	19,372	12,826
Total	2,00,587	2,35,888

Table - 16

Estimated species-wise composition and percentage in 'Alivi' nets.

Species	February-May 1965		January-May 1966	
	Weight in Kg	Percentage	Weight in Kg	Percentage
CARPS :				
P. kolus	332.846	3.9	70.990	1.9
P. dobsonii	3.920	-	5.520	0.2
P. sarana	193.360	2.3	119.720	3.3

Contd... Table 16

1	2	3	4	5
Tor spp.	1.200	-	119.720	3.3
P. stigma	13.400	0.2	35.700	1.0
P. ticto	16.000	0.2	1.000	-
L. fimbriatus	91.185	1.1	7.930	0.2
L. calbasu	1.080	-	0.750	-
L. potail	-	-	0.080	-
L. porcellus	-	-	0.200	-
L. bata	0.140	-	-	-
L. rohita	0.170	-	-	-
C. catla	13.060	0.1	-	-
C. reba	403.660	4.7	127.680	3.5
O. vigorsii	309.600	3.6	373.025	10.1
O. cotio	-	-	1.800	-
		16.1		20.2
CATFISHES :				
M. seenghala	842.135	10.0	213.090	5.8
M. aor	993.590	11.7	455.500	12.4
W. attu	1537.910	18.2	391.840	10.7
M. cavasius	1086.190	12.8	790.200	21.5
S. childrenii	174.300	2.1	393.375	10.7
P. taakree	1958.010	23.1	180.685	5.1
O. bimaculatus	249.199	2.9	344.485	9.4
M. punctatus	-	-	7.500	0.2
N. khavalchor	0.620	-	-	-
		80.8		75.8

Contd.... Table 16

1	2	3	4	5
MISCELLANEOUS :				
C. marulius	84.210	1.0	39.780	1.1
C. striatus	4.390	-	15.380	0.4
Oxygaster spp.	-	-	15.500	0.4
G. giuris	18.060	0.2	6.300	0.2
M. armatus	32.700	0.4	5.840	0.2
N. notopterus	100.360	1.2	40.900	1.1
A. ranga	-	-	7.100	0.2
Others	27.900	0.3	15.000	0.4
		3.1		4.0

Table 17

Fish Production Estimates of the Tungabhadra Reseervoir
(Corrections for the left flank production are not made in this table)

Species (1)	1958 (2)	1959 (3)	1960 (4)	1961 (5)	1962 (6)	1963 (7)	1964 (8)	1965 (9)
Total production.	15,176	10,907	28,858	24,192	24,313	68,728	1,32,898	1,56,118
CARPS :	(in tonnes)							
P. Kolus	33.33	22.70	29.35	30.00	26.36	29.51	14.32	9.40
P. dobsonii	5.45	6.80	3.05	4.48	13.75	6.00	4.06	5.00
P. pulchellus	1.08	0.62	0.52	1.35	2.08	0.97	0.07	0.40
P. sarana	4.18	1.90	1.95	0.63	1.25	2.46	1.82	3.30
Tor spp.	1.75	3.80	1.56	1.26	3.36	1.58	0.98	1.60
L. fimbriatus	22.13	19.04	7.29	13.66	10.18	8.88	5.34	6.00
L. calbasu	4.03	2.55	2.58	4.25	3.85	4.58	1.68	0.80
L. potail	1.85	1.40	1.20	6.49	1.56	1.04	1.01	-
L. porcellus	-	-	0.01	-	-	0.13	-	-
L. bata	-	-	0.15	0.01	0.04	0.10	0.08	0.01

Contd... Table 17

1	2	3	4	5	6	7	8	9
L. pangasius	0.22	0.55	0.03	0.05	0.30	–	–	–
S. nukta	0.41	0.22	0.13	0.13	0.42	0.40	0.01	–
C. reba	0.06	0.01	–	–	0.02	–	0.14	–
L. rohita	–	–	0.01	0.13	0.01	0.26	0.05	–
C. mrigala	0.01	0.05	–	–	–	0.11	0.01	–
C. catla	0.17	0.16	0.22	0.40	0.37	0.70	0.12	1.50
O. vigorsii	0.37	0.23	0.94	0.67	1.18	1.60	1.93	2.40
S. thomassi	0.02	0.08	0.17	0.16	0.11	0.20	0.01	–
T. sandkhol	0.01	0.01	–	0.01	0.01	–	0.01	–
	75.07	60.22	48.96	63.91	64.91	58.05	30.53	30.40
CATFISHES :								
M. seenghala	7.00	14.20	8.50	8.62	9.48	18.13	36.48	27.50
M. aor	4.98	8.70	24.45	4.49	2.96	7.18	11.08	11.30
W. attu	1.55	4.90	1.47	2.38	2.37	1.80	8.14	19.50
M. punctatus	0.20	0.90	1.15	0.95	1.75	0.53	1.18	1.00
M. cavasius	0.05	0.20	0.14	0.06	0.06	0.08	0.16	1.50
O. bimaculatus	0.44	2.40	1.80	0.08	0.45	1.42	1.40	2.00
O. pabo	0.14	0.32	–	0.08	0.05	0.25	0.01	–
S. childrenii	1.35	1.90	1.40	12.04	9.45	4.17	7.48	9.60
P. taakree	0.02	0.30	1.25	0.30	0.75	0.42	0.70	2.20
R. pavimentata	0.23	0.33	0.79	0.11	0.55	0.29	0.03	0.10
N. khavalchor	–	–	–	–	–	0.33	0.01	–
B. bagarius	6.19	1.90	6.05	3.86	5.27	1.51	1.23	1.0
	22.15	36.07	47.00	32.97	33.14	36.11	67.90	65.20
INFREQUENT FORMS :								
M. armatus	–	1.86	–	–	–	0.31	0.01	–
C. marulius	0.56	0.43	0.60	1.24	0.61	1.21	0.36	0.40
C. striatus	1.63	0.70	2.28	1.58	1.08	3.23	0.68	1.40
N. notopterus	0.13	0.16	0.44	0.12	–	0.45	0.21	0.30
A. nebulosa	0.21	0.06	0.30	0.06	0.26	0.19	0.31	–
Miscellaneous	0.25	0.50	0.26	0.12	–	–	–	1.70
	2.78	3.71	3.98	3.12	1.95	5.39	1.57	3.80

Table 18 gives the actual estimated figures and composition of total landings for 1963, 1964 and 1965 at Hospet Fish assembly centre, which are 69, 133 and 156 tonnes each year. There being no centralised agency through which the fish is routed, and want of communication and other difficulties, the fish landings are necessarily scattered, and are based on statistical randomised samplings.

There has been a gradual increase in total fish production from year to year in the reservoir as indicated. In the first 5 months of 1966 (January to May), the total catch is similarly estimated to be 167 tonnes due to quite heavy shore seince operations.

Table -18

Species-wise Production at Hospet Centre

Species	1963	1964	1965
Carps	(1)	(2)	(3)
P. kolus	21773.102	16509.220	14643.217
P. dobsoni	3851.142	4504.660	7855.068
P. pulchellus	432.197	704.440	635.285
P. sarana	1734.135	2379.410	5116.199
Tor spp.	843.199	1139.570	2468.939
L. fimbriatus	5168.532	6342.500	9328.822
L. calbasu	2773.012	2402.710	1283.844
L. potail	636.643	1419.562	71.298
L. porcellus	67.480	-	78.055
L. bata	7.076	9.547	8.860
L. pangusia	-	-	66.600
S. nukta	145.286	80.711	168.370
C. reba	-	151.204	0.700*
L. rohita	73.690	45.000	172.005
C. mrigala	23.518	109.690	63.754
C. catla	71.705	146.370	2391.678
O. vigorsii	1448.861	2127.393	3809.552
S. thomassi	29.130	6.374	2.419
T. sandkhol	-	5.810	5.710

Contd.... Table 18

1	2	3	4
Catfishes :			
M. seenghala	14153.934	59575.380	42920.283
M. aor	5357.789	11651.120	17600.902
W. attu	1063.063	5124.750	14075.322
M. punctatus	384.382	1862.510	1538.816
M. cavasius	1.628	208.780	2337.380
O. bimaculatus	904.021	1804.573	2962.527
O. pabo	8.265	101.334	20.190
S. childrenii	3015.841	8875.270	15032.831
P. taakree	348.276	927.670	3478.816
R. pavimentata	229.469	155.679	213.278
N. khavalchor	2.880	0.689	5.083
B. bagarius	951.096	1414.953	1645.282
Infrequent other forms :			
M. armatus	12.660	3.200	13.475
O. marulius	912.839	332.453	691.097
O. striatus	1155.246	722.896	2187.678
N. notopterus	132.524	388.156	598.443
A. nebulosa	118.840	11.740	5.766
Miscellaneous	896.956	1683.100	2621.115
	68728.380	132898.424	156188.659

* The value is low as this fish does not come to Hospet Fish Market, but is dried by fishermen.

Catchability of nets and gear is dependent upon the variability in the gear itself, depths and zones of the reservoir, turbidity, nature and substrata of fishing ground and wind and wave action. The mesh sizes and selectivity, whether these are surface or bottom gill nets, drag nets etc. further determine the catches.

The main gears like the gill nets, alivi nets and hook and line are not constantly operated throughout the year as already indicated. An estimated number of 105 gill net units of which 55 units are Telugu fishermen, 35 units Killekethas and 15 Tamil fishermen were noticed in 1964 and 1965. Each gill net unit consists of one coracle (with the exception of Killekethas), 500 m gill nets and two men. About 80% of Telugu fishermen units abandon gill net operations and took to more profitable alivi operations between January and May months. 10-12 units return to their native villages between August and January. Between August and December about 20% of the fishermen take to hook and line fishing to supplement gill net catches. Amongst Killekethas, 50% withdraw from fishing between July and December to take up agricultural activities. Hence computations of unit of fishing effort are based on actual examination of units operating each month taking into account all the above factors.

Gill Nets: Number of fishing days are computed at 20 in a month in gill net fishing, with fishing day as 12 hrs., which includes moving from camp to fishing grounds and back.

Table 19 presents the catch per effort by gill net fishermen. Unusual lowering of water level in April, May and June, yielded quite high during 1965 as compared to poorer yields in other months. The high water level from July/August to December in both years however showed poor catches by gill nets. Production of 75 tonnes and 112 tonnes in each year was attributed to gill nets respectively.

Table - 19

Catch per unit effort (in kg) in
gill nets for the year 1964 and 1965

Months	1964 Estimated catch	1964 No. of units	1964 C.P.U.E	1965 Estimated catch	1965 No.of units	1965 C.P.U.E
January	7019	1880	3.7	9890	1580	6.2
February	3193	1220	2.5	5944	1180	5.0
March	1532	1220	1.2	5745	1180	14.8**
April	2655	1220	2.1	21299	1180	18.0**
May	2943	1220	2.4	14558	1180	12.3**
June	8776	1220	7.2*	26523	1180	22.4**
July	11188	1400	7.9**	7901	1120	6.7
August	4361	1180	3.6	3830	860	4.4
September	5465	1180	4.6	5044	860	5.8
October	9361	1520	6.1	2379	1220	1.9
November	11178	1520	7.3	5430	1220	4.4
December	6438	1520	4.2	3770	1220	3.1
Total	74114	16300		112313	13980	

* The higher catches in June-July 1964 are perhaps due to gears other than gill nets operated in those months in the inundated margins of the bays during flood seasons.

** The high catches from March to June 1965 were accounted for by the low water levels reached (1590) in the reservoirs which caused good catches to be obtained in gill nets by a concentration of fishes in the Shrunken reservoir region.

Catch per unit effort was 1.2 to 7.9 kg per day in 1964 and 1.9 to 22.4 kg in 1965. Lowering of water levels added to increased production with fewer units in 1965 in gill nets. This production is however found not very high compared to Mettur and Bhavanisagar reservoirs. Production may be as high as 50 kg per unit in Bhavanisagar where fishing is restricted to only four or five units. The benefits to fishermen however is high in the Tungabhadra Reservoir as even the lower catches per net provide them a living.

Alivi Nets : Total landings (table 15) throughout the reservoir by alivi nets were estimated at 97 and 101 tonnes in 1964 and 1965 respectively. In the year 1966 from January to March, a total landing of 75 tonnes was estimated and a further 73 tonnes to the end of May 1966. Monthly catch per unit effort is also given for three years, each unit being 100 m single alivi net, two coracles and 8 men, operating for 8 hours a day inclusive of movement from camp to fishing centre and back.

A comparison of catches over four months from February to May each year shows that in earlier one or two months there is usually a better catch as fishing takes place in the upper reaches i.e. zones I and II in the main stream. There is usually a decline by April but by end of April and in May , catches rise high as fishing becomes restricted to the actual shrunken reservoir's back-wash where fish get concentrated. Catch figures are difficult to be obtained in May as alivi units cannot be reached from the right flank being remote from roads. Hence majority of fish caught is dried and disposed off to fish traders on the left flank. In fact, fresh alivi catches are sent to Koppal from which centre it is exported. The fishermen themselves transport fresh fish for 8 km by foot-path and road further adding to their labour.

An average 'alivi' having a length of about 300 m (including 200 m scare ropes on sides) semicircularly covers approximately an area of 1.4 ha of the reservoir area. Based on this fact the available standing stock of fish in the areas of operation, especially from centre A to almost opposite centres E (Tambrahalli) and D (Katharki) as the reservoir shrinks, has now been computed as follows:-

	Months	Average catch per Alivi (5 hauls).	Catch per haul. (1.4 ha)	Catch per one ha
1964	February	70.324	14.648	10.463
	March	78.297	15.659	12.527
	April	56.065	11.213	8.971
	May	118.567	23.713	18.970
1965	February	40.256	8.051	6.441
	March	95.862	19.172	15.338
	April	71.466	14.293	11.435
	May	127.831	25.565	20.453
1966	January	56.600	11.320	9.056
	February	50.941	10.188	8.150
	March	47.720	9.544	7.635
	April	120.092	24.018	19.215
	May	122.722	24.544	19.635

Catches increased from January to May with a lower rate in April 1964 and 1965 but in February and March in 1966, with rapid shrinkage in reservoir levels, there were further increases. The computed standing stock for the area is between 6.441 to 20.453 kg per ha. But it is to be understood that these catches are removed everyday steadily from January to May for nearly 130 days. As removed stock is replenished from the main deeper part of the reservoir as upper reaches in 1 to 1½ m depths in the river part, contained only meagre stocks.

<u>Hook and Line</u>: No seperate landings are possible to be computed for this method. Catches are mixed generally with gill net hauls before being brought to an assembly centre. This fishing prevails for only 15 days in a month between August and December. Average catches for 500 hooks were computed at 8 to 10 kg per day of 24 hours fishing. 2025 kg of fish are landed per month by long lining by all fishermen

(one unit-one coracle, 2 fishermen, 500 hooks and 24 hrs. fishing). Besides all catfishes, Puntius dobsoni, P.sarana, Tor spp., Osteobrama vigorsii are also taken by hooks.

Species composition:

All available species of fish in an area i.e. standing stock, are captured by seining. In table 16 and fig.11 the estimated weights together with percentages of each species are presented. The dominant fishes in 1965 are Pseudentropius taakree (23.1%), Mystus cavasius (12.8%) Mystus aor (11.7%) and other catfishes like Wallago attu (18.2%) Ompok bimaculatus (2.9) etc. Carps like Puntius kolus (3.9), P.sarana (2.3) are much lower in percentage composition than catfishes. Osteobrama vigorsii and Cirrhina reba also were available in quantity (3.6%) and 4.7%) respectively. 80.8% catfishes and 16.1% carps in weights were estimated in seine nets during 1965 and 75.8% catfishes and 20.2% carps respectively in 1966 (up to May).

While several species occurred constantly high in numbers in March, Osteobrama vigorasii occurred largest in May. The remarkable increase in March of some of the forms was due to four times more effort put in by fishing parties than in February or May, or two times more in April. The representative catches in 'Alivi' are to be taken as indicating the exact composition of fish population within the reservoir. This almost remained constant in the three years study.

Alivi operations in the Riverine Zone I and Transition Zone II reveal localisation of some fish species. M. aor dominates the catches among catfishes in centre A, followed by M.seenghala and S.childreni. P.stigma dominated (by number) at Hampasagar bay which is somewhat separated from the main river course (by elevated bank) where the water is more or less stagnant as in a tank. This provides ideal conditions for this species to breed and thrive. Concentration of C.reba (particularly juveniles) is observed in the main river course at centre C where river conditions suit this species. Further M.cavasius, P.taakree, P.goongwaree and O.bimaculatus occur constantly in catches in this area and a little lower as the water recedes. These four species and C.reba appear to be localised in this II Zone having been washed as larvae or fry during floods. S.childrenii move in shoals, as they were recorded in large numbers in some alivi hauls but completely absent in others. Mystus cavasius also occurs in alivi hauls, and is similar in habits to shoals of M.gulio within Bengal estuaries.

Operations of shore seines in the Tungabhadra reservoir can capture most predatory catfishes which dominate the reservoir; hence such operations are to be encouraged as they remove almost all catfishes to an extent of 80.8%. In May 1966, even 100% catfish are recorded in some hauls.

The productive Zones I, II and III contain up to 80% of catfish (by weight) and above 90% or so by numbers. Minor and most weed or trashfishes like Osteobrama species, Cirrhina reba, Puntius stigma, P. ticto etc., are also removed. Much of the uneconomical P.kolus is also destroyed and all these are beginning to be reflected in the fish composition over the 3-4 years the nets are under operation. Very few adult carps, or young of local or introduced carp fingerlings or juveniles are noted in such catches. Obviously such fishes of value were absent within the reservoir.

A few adults which may breed above in the reservoir are also caught occasionally with some of the introduced major carp juveniles. But with certain restrictions in operations of shore seines such as seasonal or monthly licencing system, prohibition in catching of a particular size or species (from time to time) and by effective supervision and check, these minor difficulties can be overcome. Even an increase in mesh sizes from the present

15-25 mm to 25-30 mm may help locally breeding forms. Cat fish population however is being gradually eliminated from the reservoir. But it will be apparent from recruitment trends that the catfishes cannot entirely be eradicated as they are brought into the reservoir in large numbers from the river above.

Species composition based on twice-thrice weekly random sampling at Hospet fish assembly cum fish market is presented already in table 18. Since 1964 there has been no selectivity as to species and size as alivi nets removed all available fish unlike gill nets, which by their very nature (mesh sizes, depths, areas of operation etc.) did not indicate a correct picture of fish composition. But they roughly indicate a carp fish population of 58.80% to 75.07% dominated mainly by Puntius kolus to an extent of 22.70% to 33.00%. But these figures are subject to error as catches were not fully analysed at Hospet fish market and represent the catchable fish rather than standing stock.

Later in part of 1963 through 1964 and 1965, the composition structure is complete on the entire reservoir based on catches from all types of gear. It is found with an increase in total catch from 1963 to 1965, composition also changed appreciably, carp population being reduced to 30.53 and 33.72% , at the same time, catfish having increased to 67.90 and 60.95% respectively during 1964 and 1965. Puntius kolus was reduced to 8.71% of total weight of fish captured, other carp species remaining almost static. Among catfishes, dominating Mystus seenghala and M.aor showed a remarkable increase between 18.13 to 34.22% and 7.18 to 11.08% respectively, followed by Wallago attu (8.14 and 11.50 in 1964 and 1965) and Silonia childrenii 7.48 and 8.10%. This increase is based on their increased capture in 'alivi'.

In the following page, the data on the actual range in sizes commonly recorded in gill and alivi nets (of species) are presented along with maximum sizes attained.

Species	Common length ranges in commercial catches (mm)	Maximum total length attained or recorded (mm)
P.dobsoni	270-510	810
P.kolus	230-350	496
P.sarana	205-275	346
L.fimbriatus	276-670	720
L.calbasu	270-580	730
O.vigorsii	215-325	395
M.seenghala	410-1030	1300
M.aor	310-770	1100
W.attu	470-790	1250
B.bagarius	335-850	1600
S.childrenii	270-510	735
P.taakree	205-385	430

(Based on the Hospet fish assembly centre and common occurrence in the fish population).

Following serves to give a fair idea of various species in commercial catches over the few years.

Puntius kolus : Fishery of this medium riverine carp,well established in the reservoir on account of its extensive breeding and adaptability to reservoir conditions shows a dwindling trend from 22 tonnes in 1963 to 15 tonnes in 1965 and 33.33% by weight in 1958 to 9.40% in 1965. Selectivity of gill nets (Rangoon nets and Uduvala) that were being operated until 1963 mainly accounted for their capture being high by weight. Decline in 1964 and 1965 is due to introduction of 'alivi' operations which capturing more catfish, relegated P.kolus to the background. It does not however mean that P.kolus has declined in population. A decline in P.kolus population in the reservoir, if proved is attributable to its extensive elimination by alivi operations. Composition in alivi of this form is 3.9 and 1.9 in 1965 and 1966, which appears to present a true picture of its composition by weight in the reservoir.

..2

P.dobsoni : The species has increased from 3.8 to 7.8 tonnes between 1963 and 1966. Percentage by weight of this major Tungabhadra river carp has varied from 3.05 in 1960 to 13.75 in 1962, but has remained almost constant between 4.06 (1964) to 6.00 (1963) and 5.00 in 1965. The fish is usually caught in gill nets, but very seldom in alivi. It forms the third largest catch by weight in gill nets as even the few specimens caught, weigh considerably high. Its occurrence however is more frequent in Zones I and II.

P.pulchellus : This species common in the main river, is rarely recorded in the reservoir being only 0.4 to 0.7 tonnes in three years and between 0.07 to 0.97% between 1963 and 1965. Although a major carp, it holds negligible scope as a possible fish that could be grown in the reservoir. In some reservoirs of the drainage (Anjanapur reservoir) the fish dominates as a fishery and probably may improve in the Tungabhadra reservoir.

P.sarana : By numbers this medium fish adds considerably to carps within the reservoir, though by weight, composition has varied between 0.63 (1961) to 4.18% in 1958 but 1.82 and 3.30% in 1964 and 1965 respectively. Its production has increased from 1.7 tonnes in 1963 to 5.1 tonnes in 1965. Young of this species are common in alivi catches, but adults are few. In gill nets (small sized meshes) the fish is common, adults appearing in great numbers between May and July, when they also spawn in the reservoir.

Tor spp. : The mahseers- Tor mussullah and T.khudree occur in the reservoir especially in the post-monsoon months between August and December in Zones I and II. Juveniles of 0 to 0 + 1 year occur in the gill nets and also in alivi catches. The percentages by weight have varied from 1.60 in 1965 to 0.94 in 1964. Their production has ranged from 0.84 tonnes in 1963 to 2.40 tonnes in 1965. Occasionally larger sizes are recorded.

Labeo fimbriatus : This dominates the Tungabhadra river as a major carp, though growth appears slow. In earlier years with the formation of the reservoir, the species appears to have initially occured in considerable quantity. It was estimated at 5.16 to 9.30 tonnes from 1963 to 1965 and was 22.13% in 1958, 19.04% in 1959, and ranged between 7.29 and 13.66 until 1963. It is stabilised at 5.34 and 6.00% in 1964 and 1965. Young L.fimbriatus occur commonly in shore seines but well grown specimens in numbers in April-May mainly in gill net catches. The fish has been gradually eliminated even though individuals appear to prefer riverine conditions. Its increasing production is however due to increased fishing effort.

Labeo calbasu : Though mainly adults have been obtained to an extent of 4.58% in weight in 1963, the quantity has remained 1.68% and 0.80% in 1964 and 1965; mainly adults appeared in gill nets. The form has occurred in declining quantity over the last three years (2.77 to 1.28 tonnes).

Labeo potail, L.porcellus and L.bata: These three medium forms occur occasionally in catches. Though their spawn has been recorded in considerable quantity at centre A, young ones are not found except as stray forms in the reservoir.

Cirrhina reba: This minor species though forming 4.8% by weight of 'alivi' catches in 1965, in total landings in the reservoir it has seldom exceeded 0.14% (in 1964). However, even in 'alivi' catches, it is found only in the reservoir part, close below Hampasagar in great numbers than in other sections where it occurs rarely. Large quantities of spawn have been obtained at centre-A during monsoon floods, and the young survive only in certain areas. A total weight of 404 kg in 1965 exceeds any other single carp species in 'alivi' catches.

Gangetic major carps : Gangetic major carps said to be stocked in the reservoir by the Tungabhadra Board authorities, have varied only between 0.01 to 0.26% in the case of Labeo rohita, 0.01 to 0.11% in Cirrhina mrigala and 0.12 to 2.40% in Catla catla during any of eight years of study. Individuals that are occasionally recorded are obviously those stocked as fry or fingerlings by the Tungabhadra Board. During 1964 and 1965 an estimated weight of 146.370 and 2391.678 kg of C.catla was recorded based on the 94 specimens weighing 277.298 kg and 120 specimens weighing 583.674 kg at Hospet. These stray specimens of quality carps indicate poor if not absence of stocking of the reservoir or elimination of stocked fish by death or escapement into the river above. Their progency have not been recorded any time in the reservoir indicating absence of their spawning.

Osteobrama vigorsii : This is considered a 'trash' fish. Being compressed laterally, full of bones and highly predaceous its value in the fishery is poor, though considerable numbers are caught both in gill and 'alivi' nets. Its production has increased from 14.48 tonnes in 1963 to 38.09 tonnes in 1965 due to intensified fishing. Its capture from 0.23 in 1959 to 2.40% in 1965 indicates its heavy population. Its capacity to breed within the reservoir and predaceous feeding habits have no doubt contributed to its resident population being on the increase.

Mystus seenghala : The most dominant form in the reservoir accounting for also the maximum value in fish trade is M.seenghala. This alove has contributed singularly to 36.48 and 27.50% in 1964 and 1965, and has ranged from 18.13% in 1963 to 7.00% in 1958. Actual production was estimated at 14.15, 59.57 and 42.92 tonnes in 1963, 1964 and 1965 respectively. Both maturing and juvenile forms are common in gill and 'alivi' nets. Since no breeding specimens are found, all the individuals obtained are recruited from the river above, with ready to spawn specimens ascending into the main river. Increased catch is due mainly because of shore seine operations, where specimens caught are all juveniles on maturing.

Mystus aor : This related species also shows an increase from 5.35 to 17.60% tonnes between 1963 and 1965 owing to extensive shore seine operations. The species however is not as frequent as M.aor. Percentage composition has been 7.18, 11.08 and 11.30 during the three years of study from 1963 to 1965.

Wallago attu : While some 1.06 and 5.12 tonnes of this fish were caught in 1963 and 1964, as much as 14.07 tonnes were removed in 1965 owing to alivi nets. Percentage composition was 1.8, 8.14 and 9.00 in 1963, 1964 and 1965 respectively. This species also has never been found in a breeding state. The species is recruited from the river above.

Silonia childrenii : This species (known earlier as Silanopangasius childrenii or Silonia sykesii) has formed a major fishery in the reservoir, ranging from 3.01 and 8.87 tonnes in 1963 and 1964 to 15.03 tonnes in 1965. Its percentage composition has been 4.17,7.48 and 9.60. This species is a monsoon breeder in the river above, and its dominant fishery in the reservoir to the extent noted is peculiar. Only maturing stages of this fish are available, fully mature form and fingerlings being absent.

The four catfishes above mentioned are the major fish species in the Tungabhadra reservoir, surpassing individually any other species of carps in value. Besides other medium sized catfishes further add to the value. Mystus cavasius though ranging from 0.08, 0.16 and 1.50% in the three years, contributed 0.2 and 2.15 tonnes in 1964 and 1965. Similarly Ompok bimaculatus ranged from 1.42 to 2.00% and contributed 0.90,1.80 and 2.9% tonnes respectively. Pseudentropius taakree, contributed 0.34, 0.92 and 3.40 tonnes and 0.42, 0.70 and 2.20% from 1963 to 1965. Many medium and minor carps and catfishes such as Oxygaster spp.,Aspidoparia spp., Puntius spp., Rohtee spp., Cirrhina reba, Mystus cavasius, Ompok spp., Pseudentropius taakree, P.goongwaree, smaller Mystus seenghala, M.aor, Wallago attu etc., are sun dried. The data on such dried fish is only partially available. It was estimated that at least 25-30% of total, alivi catches is sundried when fresh fish is not lifted. Hence, the estimated landings of fisheries is much more than the modestly computed figures now given.

PART IV

EXPERIMENTAL FISHING

EXPLOITATIONAL EXPERIMENTS WITH GILL-NETS.

Storage reservoirs in India were first thoughtto be highly productive, but later investigations revealed that unless properly stocked and conserved as in Mettur, Bhavanisagar and D.V.C reservoirs, fish yields from such storage reservoirs can be very low. Their production cannot be calculated on the basis of water spread alone. Some reservoirs are fairly productive with fish forms natural to the respective river drainages entering them as in Krishnarajasagar, a few reservoirs in Madhya Pradesh and Andhra Pradesh. Majority of reservoirs being within deep basins or ravines, and submerging forest lands, remain unexploited even for whatever 'wild' fish that may be available. In recent years (1960-1964), the Central Inland Fisheries Research Institute for services of two F.A.O experts (from Russia) to familiarise the country's fishery Biologists, Fisheries Departmental staff from States and Fishermen with techniques of removal methods from such deep reservoirs. Their findings indicate that fish stocks remaining unexploited over a few years for want of boats and venturesome fishermen, can be removed more effectively by modifying the usual gill nets by changing the hanging coefficient of webbings to 0.5 to suit the shape of the fish and by providing sinkers and floats correctly. Also in place of narrow bottom nets- 'Uduvala', i.e. broader, wellhung bottom nets could be employed for better purpose. Initially though successful, continued use of such nets has brought about a stalemate for the simple reason that fish stocks are not maintained by correct stocking and management and natural recruitment not fostered. When richer fish harvests can be had, most reservoirs can be effectively fished only by gill nets rather than shore seines and other more conventional methods familiar to the Indian fishermen.

Since the Tungabhadra reservoir is already being exploited by surface gill nets, shore seines and long lines, no new device for exploitation was necessary. Experimental fishing programme was hence directed mainly to ascertain the more efficient meshes with the species and sizes of fishes that can effectively be caught in each mesh or areas of fish concentrations. Range of depths where bottom nets could be operated were between 7-20 m only,precluding'deep water' fishing experiments.

Though initiated in 1960, surface gill net operations were restricted close to the Dam site until 1963. Between 1963 and 1966, extensive areas were covered comprising all the seven centres chosen for biological observations, various pockets, bays and the riverine stretch above. Bottom gill nets were introduced in February 1965 and operations carried out over the year except in July-August (due to bad weather).

The emprical data is presented in tables 20 and 21.

Description of Nets :

Nets employed were the now familiar nylon twine nets of following specifications :-

Specifications:	Mesh bar
210/1/2	30 & 40 mm
210/2/2	40 & 50 mm
210/1/3	50 & 60 mm
210/2/3	60 & 70 mm
250/2/3	70 & 80 mm
250/3/3	100 &150 mm
250/4/3	100 &150 mm

Surface and bottom set nets were identical in all respects, maintaining uniform lengths,heights, meshes etc. and operated simultaneously at each centre together. While hung, the webbings of 60 m length and 6 m width, were 30 m in length and 5 m in height.

Table-20

Zonewise species composition in 1964.

Species	Mudalighatti No/kg %	Sovinahalli No/kg %	Hampasagar No/kg %	Katharki No/kg %	Tambrahalli No/kg %	Karkihalli No/kg %	Damsite No/kg %
1	2	3	4	5	6	7	8
CARPS :							
P.kolus	79/35.110 68.5	206/81.925 38.2	523/188.110 42.3	57/20.317 15.1	187/73.738 18.1	7/2.541 13.7	66/23.368 25.2
P.sarana	3/0.950 2.0	26/8.535 4.0	21/6.375 1.4	24/6.270 4.7	54/12.274 3.0	1/0.230 1.3	29/6.628 7.2
P.dobsoni	-	28/13.360 7.6	63/35.960 8.1	1/0.200 0.2	20/15.092 3.7	3/1.697 9.2	29/14.777 16.0
P.pulchellus	-	1/6.300 2.8	4/10.085 2.3	-	4/9.530 2.3	-	-
Tor spp.	-	4/22.650 10.6	2/20.000 4.5	-	1/0.350 0.1	-	3/5.484 5.9
L.fimbriatus	2/4.500 9.4	10/4.660 2.2	38/20.900 4.7	37/20.055 14.9	65/37.383 9.2	3/1.090 5.9	6/2.230 2.4
L.calbasu	-	7/3.820 1.8	2/0.850 0.2	5/3.120 2.3	10/7.501 1.8	1/0.470 2.5	3/2.903 3.2
L.bata	-	-	1/0.670 0.1	-	-	-	-
L.potail	-	-	-	-	2/0.626 0.2	-	-
C.catla	-	4/1.340 0.6	3/38.403 8.6	3/47.500 35.4	10/58.698 14.4	-	-
C.mrigala	-	1/2.948 1.4	-	1/0.380 0.3	-	-	-

Contd. Table-20

1	2	3	4	5	6	7	8
C.reba	-	-	-	2/0.605 0.5	2/0.735 0.2	-	-
O.vigorsii	7/1.470 3.0	73/12.430 5.8	91/17.094 4.0	30/4.793 3.6	70/11.728 2.9	1/0.300 1.6	33/7.323 7.9
CATFISHES :							
M.seenghala	2/2.000 4.1	9/12.170 5.7	10/24.560 5.5	8/7.261 5.4	52/53.827 13.2	5/8.531 46.0	9/10.760 11.6
M.aor	-	2/1.370 0.6	1/0.810 0.2	13/10.521 7.8	30/24.887 6.1	2/1.248 6.7	2/1.122 1.2
W.attu	1/1.270 2.6	8/13.346 6.4	24/31.388 7.0	1/0.415 0.3	35/46.045 11.3	-	-
M.punctatus	-	-	-	-	2/16.300 4.0	-	-
B.bagarius	1/3.500 7.2	-	1/0.750 0.2	-	-	-	-
S.childrenii	3/1.350 2.8	45/24.[illegible]80 11.6	76/45.026 10.1	24/10.780 8.0	45/28.470 7.0	5/1.939 10.5	46/16.678 18.0
P.taakree	-	10/0.720 0.3	15/0.070 0.7	6/1.745 1.3	5/1.045 0.3	2/0.485 2.6	6/0.684 0.7
O. bimaculatus	-	-	1/0.130 0.0	1/0.140 0.1	3/0.405 0.1	-	-
O.pabo	-	-	1/0.250 0.1	-	-	-	-
R.pavimentata	-	2/0.590 0.3	-	-	5/1.500 0.4	-	-
M.cavasius	-	-	-	-	1/0.110 0.0	-	-

1	2	3	4	5	6	7	8
MISCELLANEOUS :							
T.sandkhol	-	-	-	-	2/0.440 0.1	-	-
N.notopterus	1/0.200 0.4	1/0.180 0.1	1/0.140 0.0	1/0.180 0.1	38/6.403 1.6	-	-
N.khavalchor	-	1/0.030 0.0	1/0.050 0.0	-	1/0.045 0.0	-	2/0.080 0.1
Oxygaster spp.	-	-	-	-	1/0.105 0.0	-	-
	99/48.350	438/214.354	879/445.252	214/134.291	645/407.237	30/18.531	236/92.596

Table-21

Zonewise species composition in 1965

Species	Mudalighatii No/kg %	Sovinahalli No/kg %	Hampasagar No/kg %	Katharki No/kg %	Tambrahalli No/kg %	Karkihalli No/kg %	Dam site No/kg %
1	2	3	4	5	6	7	8
CARPS :							
P.kolus	98/49.822 15.2	78/33.970 16.3	228/110.405 49.2	24/10.086 17.1	313/112.839 26.5	4/0.950 11.4	445/197.931 36.3
P.sarana	17/2.900 0.9	16/2.710 1.3	13/2.520 1.1	3/0.580 1.0	131/26.250 6.2	4/0.440 5.3	64/12.545 2.3
P.dobsoni	40/32.395 9.9	13/4.956 2.4	13/12.610 5.6	1/0.438 0.7	19/8.832 2.1	-	42/35.487 6.5
P.pulchellus	2/7.250 2.2	-	-	-	3/1.830 0.4	-	5/7.403 1.4
Tor spp.	6/6.510 2.0	-	1/0.310 0.1	-	1/0.200 0.0	-	18/14.847 2.7
L.fimbriatus	41/23.560 7.2	14/7.620 3.7	18/10.130 4.5	10/4.280 7.3	85/52.117 12.2		59/28.441 5.2
L.calbasu	4/2.030 0.6	1/0.070 0.0	-	-	5/2.092 0.5	1/0.250 3.0	19/11.999 2.2
L.potail	-	-	-	-	-	-	2/0.660 0.1
C.catla	-	2/0.890 0.4	3/0.930 0.4	1/19.00 32.3	8/5.412 0.3	1/0.600 7.2	5/17.600 3.2
C.mrigala	-	2/2.500 1.2	-	1/1.800 3.1	1/0.680 0.2	-	-
C.reba	1/0.320 0.1	-	-	4/0.780 1.3	-	-	1/0.180 0.0
O.vigorsii	153/29.545 9.0	222/40.024 19.2	131/38.225 17.0	27/3.483 5.9	419/59.260 13.9	8/1.280 15.4	259/57.661 10.6
O.neilli	-	-	-	-	-	-	1/0.298 0.0

Contd..Table-21

1	2	3	4	5	6	7	8
CATFISHES:							
M.seenghala	21/19.825 6.1	5/5.090 2.0	10/8.780 3.9	4/4.260 7.2	55/38.490 9.0	-	33/19.747 3.3
M.aor	33/37.085 11.4	15/17.365 8.3	8/6.618 3.0	7/3.650 6.2	45/16.558 3 .9	1/0.0770 2 .1	29/15.622 2.8
W.attu	31/28.085 8.6	30/23.555 11.3	28/8.472 3.8	3/2.890 4.9	32/15.988 3.8	1/0.600 7.2	17/17.118 3.1
M.punctatus	1/15.000 4.5	-	1/14.000 6.2	1/0.400 0.7	2/0.610 0.1	-	-
B.bagarius	-	2/1.920 0.9	-	-	-	-	-
S.childrenii	77/52.072 15.9	74/51.925 24.9	17/7.410 3.3	10/6.589 11.2	147/71.610 16.8	3/1.540 18.6	124/74.637 13.7
M.cavasius	-	-	-	-	2/0.300 0.1	-	2/0.190 0.0
P.taakree	32/6.198 1.9	28/4.522 2.2	12/2.820 1.3	3/0.516 0.9	19/3.300 0.8	6/1.190 14.3	54/13.808 0.5
O.bimaculatus	9/1.050 0.3	2/0.230 0.1	2 /0.230 0.1	1/0.130 0.2	8/1.585 0.4	-	6/0.490 0.1
O.pabo	-	-	-	-	-	-	1/0.135 0.0
R.pavimentata	24/10.395 3.2	27/11.045 5.3	6/1.090 0.5	-	4/0.860 0.2	3/1.290 15.5	52/16.905 3.1

Contd.. Table-21

1	2	3	4	5	6	7	8
MISCELLANEOUS :							
C. striatus	2/2.530 0.8	-	-	-	2/0.510 0.1	-	-
T.sandkhol	-	-	-	-	-/0.835 0.2	-	-/1.000 0.2
N.notopterus	2/0.390 0.1	-	-	-	31/5.745 1.3	-	-
N.khavalchor	-	-	-	-	1/0.070 0.0	-	9/0.054 0.0
Oxygaster spp.	2/0.160 0.0	-	-	-	-	-	7/0.340 0.0
	596/227.349	531/208.392	541/224.612	100/58.882	1327/426.070	32/8.310	1256/545.403

Webbings were attached to the head and foot ropes by 5 or 6 (code) nylon cord. No 10 to 16 nylon multifilament ropes were used as head,foot and breast ropes. A selvedge formed usually of a thicker twine (code 3), was incorporated 2 meshes from the edge all round the webbing.

Floats and sinkers were not permanently fastened but tied during usage. Plastic floats were employed when necessary. Only a few sinkers were attached to the surface gill nets to provide stability during wind action and to prevent nets being rolled. Floats were fixed generally at 10 mm and sinkers at 5 m intervals in the case of bottom set gill nets only.

Operation :

Generally 3 to 4 nets of several meshes were joined together to form a single unit of between 90-120 m in length. Two surface and bottom units were operated generally. The master floats and master sinkers (granite stones) were fastened by strong anchoring coir ropes from float lines on either side of each set of nets to prevent drifting. When nets were operated in centres A, B and C where water currents tended to drift the nets, anchoring ropes were suitably weighted and lengthened two to three times the normal height. Due to shallower depths, seperate surface or bottom nets could not be operated in the upper stretch as the height of the net itself was as deep as the water. But in such cases the nets were firmly anchored at the bottom rather than be allowed to hang from the surface as a wall.

The fishing unit consisted of two fishermen, one coracle and between 420 to 660 m nets of all types. The higher meshed nets were used along with more efficient smaller meshed ones so that if bigger fish were available they could also be caught. But where no fish were captured such higher meshed nets a re not taken into account. The sets were laid parallel or perpendicular to the shore in depths from 5 to 20 m. The bottom nets were designed to stand erect some 0.5 to 0.75 m above the bed. The nets were generally set towards the evening and examined next morning. They were rearranged or steadied if required and later examined every 24 hours over a 3-4 da period at each centre.

The meshwise catches, lengths and weights of fishes, head and body girths, sex, condition of gonads, fullness of stomach and food were noted as the case may be.

Analyses of catch statistics:

In all, a total of 2541 fishes referable to 28 species and weighing 1360.611 kg in 1964 and 4383 fishes weighing 1799.021 kg in 1965 were caught during the operations. Details relating to the catches- species, numbers, weights and relative percentages by weight are dealt centrewise and are given in tables 20 and 21.

In centre A (Mudalighatti), Silonia childrenii dominated the catches, accounting for 15.9% by weight, followed by Puntius kolus (15.2%), Mystus aor (11.4%), P.dobsoni (9.9%), Osteobrama vigorsii (9.0%), Wallago attu (8.6%) Labeo fimbriatus (7.2%), Mystus seenghala (6.1%) and Rita pavimentata (3.2%).

In Sovinahalli Centre, S.childrenii dominated (24.9%) followed by O.vigorsii (19.2%), P.kolus (16.3%), Wallago attu (11.3%) and M.aor (8.3%), while M.seenghala is only 2.5%. Still lower down at centre C- Hampasagar, P.kolus dominated (29.2%) followed by O.vigorsii (17.0%)

In the Katharki bay (D) P.kolus dominated (17.1%), S.childrenii, L.fimbriatus, M.seenghala, M.aor and O.vigorsii being respectively 11.2, 7.3, 7.2, 6.2 and 5.9%. The solitary occurrence of Catla catla accounting for 32.2% of the total weight is fortuitous and is not taken into account here.

At Tambrahalli- Centre E, *P.kolus* dominated. (26.5%) with other forms being almost similar in composition to centre D indicating that these two middle bays attract fishes for the duration of high water.

In the deepest part of the reservoir-karkihalli (Centre F) and Vyasankere (Centre G), dominant species are *S.childrenii P.kolus* and *O.vigorsii*. All other species like *Rita pavimentata*, *P.taakree*, *M.seenghala*, *M.aor* etc also occurred.

From the data now available, the distribution of various species throughout the reservoir is found almost uniform based on experimental fishing data. Alivi net analysis, however, provides a different picture. Details relating to the total weight of fish caught, numbers of fishing days and catch per day are given in table 23.

It is apparent that the upper Riverine and Transition stretch of the reservoir from Mudalighatti to Hampasagar with catch per day ranging from 4.835 to 6.124 kg in 1964 and 6.070 to 9.627 kg in 1965, and shallower bays of zone III with 4.155 to 6.714 kg in 1964 and 6.001 to 8.411 kg in 1965, are relatively richer than the deeper zone IV (catch per day 2.204 to 4.632 kg in 1964 and 1.362 to 5.993 kg in 1965). The higher values in 1965 at all centres is due to operation of bottom gill nets.

It was further observed that Mudalighatti, Govinahalli and Hampasagar centres (A,B &C) from the river's connection with the reservoir for some 38 km below in the Transition Zone where fluviatile conditions are perceptible, have consistently indicated bigger species of fish. In the 30 and 65 mm (bar) meshed nets at Mudalighatti ,83 specimens weighing 12.06 kg were caught in 30 mm net but 14.89 kg for 9 specimens was recorded in the 65 mm net. Similarly in bottom set net as against 141 specimens weighing 27.43 kg (30 mm net), 34 specimens weighing 25.04 kg (50 mm net) were obtained. Larger specimens have been recorded with less number of fishing days in the upper centres.

Table -22

Relative richness of the 7 fishing zones of Tungabhadra Reservoir for the years 1964 &1965

	Total Wt. (kg)	Total No. of fishing days in the year.	Catch per day (kg)	Estimated Wt for the year (kg)
1964				
Mudalighatti	48.350	10	4.835	1769.610
Sovinahalli	214.354	35	6.124	2241.384
Hampasagar	445.252	78	5.721	2093.886
Katharki	134.291	20	6.714	2457.324
Tambrahalli	407.237	98	4.155	1520.730
Karkihalli	18.531	4	4.632	1695.312
Damsite	92.596	42	2.204	806.660
1965				
Mudalighatti	327.349	34	9.627	3513.855
Sovinahalli	208.392	23	9.060	3306.900
Hampasagar	224.612	37	6.070	2215.550
Katharki	58.882	7	8.411	3070.015
Tambrahalli	426.076	71	6.001	2190.365
Karkihalli	8.310	5	1.662	606.630
Damsite	545.403	91	5.993	2187.445

Gear Efficiency:

In table 23, the catches from several mesh sizes, are shown. Smaller meshed served to capture more numbers of smaller and medium fishes unlike the larger meshed nets which caught few major fishes. There is however no comparison between the two ranges in total yield. Efficiency of meshes as to total number of fish caught, total weights, number of net days, average catch per net (in kg) and average catch per unit area (in gms) have been calcutated for both years.

30,40,45 and 50 mm (bar) meshed nets were invariably more efficient, weights of fish removed per net ranging from 0.591 to 1.125 kg in 1964 and 1.167 to 1.332 kg in 1965. These are in great contrast to values of 0.004 to 0.214 kg in 1964 and 0.072 to 0.997 kg in nets ranging between 60 and 155 mm (bar) nets. The experimental gill net catches as per sizes and efficiency are also comparable to commercial fishermen's catches who caught 1.2 to 7.9 kg in 1964 and 1.9 to 22.4 kg in 1965 by employing only the required nets from time to time.

Table - 23

Number and weight per net meshwise for the years 1964 & '65

	Total No. of fish caught	Total Wt. in kg.	No. of net days for the year (Times)	No. per net	Wt. per net in kg.	Catch per unit area (gms.)
1964						
30 mm	50	8.155	-	-	-	-
35 mm	35	8.165	-	-	-	-
40 mm	1656	588.765	523	3.2	1.125	0.0075
45 mm	427	191.622	264	1.6	0.726	0.0048
50 mm	269	166.775	282	0.9	0.591	0.0039
60 mm	3	3.221	15	-	0.214	0.0014
65 mm	25	27.135	168	-	0.161	0.0010

Contd. Table-23

1	2	3	4	5	6	7
80 mm	24	38.282	180	- -	0.212	0.0014
90 mm	6	17.796	99	-	0.179	0.0012
105 mm	11	44.315	350	-	0.127	0.0008
115 mm	10	39.390	264	-	0.149	0.0010
125 mm	14	80.063	329	-	0.243	0.0016
140 mm	1	0.310	85	-	0.004	-
155 mm	10	127.836	278	-	0.460	0.0030
1965						
30 mm	802	108.416	287	2.8	0.378	0.0025
35 mm	397	87.924	66	6.8	1.332	0.0088
40 mm	1597	555.788	374	4.3	1.486	0.0099
45 mm	891	406.094	320	2.9	1.269	0.0084
50 mm	571	380.487	326	1.8	1.167	0.0077
60 mm	25	28.518	286	-	0.997	0.0066
65 mm	42	66.612	205	-	0.325	0.0021
80 mm	29	53.197	343	-	0.155	0.0010
90 mm	7	29.245	279	-	0.105	0.0007
105 mm	6	24.000	332	-	0.072	0.0004
155 mm	12	40.740	351	-	0.116	0.0007
125 mm	4	18.000	136	-	0.132	0.0008

In table 24 catches obtained by surface and bottom nets are indicated for the deeper zone for April, May and June 1965. A total of 165. 993 and 61.984 kg of fish were obtained in the bottom set nets as against 61.651 and 40.435 kg of fish in surface nets. In August-September 1965 surface nets caught 72.994 and bottom nets 81.992 kg at Vyasankere (table 25) .

Table-24

Catch statistics at various centres and in different surface and bottom nets
(During April, May and June 1965)

Species	DAMSITE (17 Days)				KARKIHALLI (6 Days)				T.B.Halli(12D)		(HAMPASAGAR 5)		SOVINAHALLI(3D)	
	Bottom Set		Surface Set		Bottom Set		Surface Set		Surface Set		Surface Set		Surface Set	
	Wt. in kg.	%	Wt. in kg.	%	Wt. in kg	%	Wt. in kg	%	Wt. in kg	%	Wt. in kg	%	Wt. in kg	%
P.kolus	67.352	40.57	24.249	29.44	26.566	42.85	25.005	61.88	56.284	45.82	5.700	25.2	0.840	1.9
P.dobsonii	18.960	0.42	8.533	13.86	-	-	1.978	4.91	2.955	2.40	6.680	3.0	0.750	1.7
P.sarana	2.827	1.70	2.0[illegible]8	3.27	1.710	2.75	0.340	0.85	2.370	1.93	-	-	0.270	0.6
P.pulchellus	3.993	2.40	-	-	-	-	-	-	-	-	-	-	-	-
Tor spp.	5.594	3.37	2.245	3.64	-	-	-	-	-	-	-	-	-	-
L.fimbriatus	15.022	9.05	3.233	5.24	0.590	0.95	0.960	2.38	6.925	5.63	0.650	2.9	0.850	1.8
L.calbasu	4.720	2.84	-	-	0.950	1.53	-	-	-	-	-	-	-	-
C.catla	0.750	0.46	0.850	1.38	-	-	-	-	0.680	0.54	-	-	-	-
O.vigorsii	24.398	14.70	11.061	17.96	4.360	7.03	6.345	15.92	18.583	15.12	2.750	12.2	2.610	5.9
M.seenghala	7.280	4.39	1.6[illegible]5	2.74	3.893	6.28	1.917	4.74	14.298	11.63	1.120	5.0	-	-
M.aor	5.298	3.19	1.739	2.82	1.750	4.83	1.100	2.72	8.700	7.08	0.440	1.8	9.040	20.4
W.attu	3.658	2.20	0.690	1.12	3.190	5.15	-	-	4.820	3.92	6.570	29.1	2.500	5.6
M.punctatus	-	-	-	-	-	-	-	-	0.950	0.74	-	-	1.070	2.4

Contd.. Table-24

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
S.childrenii	3.630	2.19	4.198	6.81	12.359	19.94	2.270	5.61	5.811	4.78	3.710	16.6	25.510	57.4
P.taakree	1.556	0.94	0.823	1.34	6.596	10.64	0.500	1.24	-	-	0.750	3.3	0.560	1.3
O.bimaculatus	0.125	0.08	-	-	-	-	-	-	0.205	0.17	0.220	0.9	-	-
N.khavalchor	0.020	0.01	0.096	0.15	0.030	0.05	0.020	0.05	-	-	-	-	-	-
R.pavimentata	-	-	-	-	-	-	-	-	0.360	0.29	-	-	0.450	1.0
T.sandkhol	0.810	0.49	-	-	-	-	-	-	-	-	-	-	-	-
Oxygaster spp.	-	-	0.140	0.12	-	-	-	-	-	-	-	-	-	-
Total ---	165.993	100.0	61.651	100.00	61.984	100.00	40.435	100.00	122.890	100.00	22.590	100.00	44.420	100.00

Table - 25

Catch stitistics at Dam site for bottom and surface nets (during August and September 1965).

Species	Bottom set Wt. in kg	%	Surface set Wt. in kg	%
P.kolus	32.056	37.8	12.990	17.9
P.dobsonii	-	-	18.830	25.9
P.sarana	0.350	0.4	0.210	-
Tor spp.	2.490	3.2	0.270	-
L.fimbriatus	4.049	4.8	4.455	6.1
L.calbasu	2.285	2.7	1.040	1.4
O.vigorsii	7.162	8.6	1.069	1.4
O.neilli	0.098	0.1	0.200	-
T.sandkhol	0.250	0.3	0.240	-
W.attu	2.410	3.2	0.920	0.1
M.aor	2.770	3.3	2.700	3.8
S.childrenii	21.134	25.6	29.065	39.9
P.taakree	0.610	1.5	0.620	-
M.cavasius	0.190	0.2	-	-
R.pavimentata	6.100	7.4	0.170	-
Oxygaster spp.	-	-	0.080	-
Total	81.992	100.0	72.994	96.5

Table-26

The catch per net per day (kg) at different centres. catch per unit area (grams per m^2)

(During April, May and June 1965).

Centres		40 mm	45 mm	50 mm	65 mm
Sovinahalli	B.	2.353 / 18.8	3.123 / 26.0	1.693 / 14.1	0.923 / 7.7

Contd.. Table 26

Sovinahalli	S.	0.707 / 5.7	1.407 / 11.7	2.660 / 17.2	2.663 / 21.9
Hampasagar	B.	1.354 / 11.2	0.422 / 0.6	0.292 / 2.0	0.704 / 5.9
	S.	0.474 / 3.9	3.123 / 26.0	0.472 / 3.9	0.152 / 1.2
Karkihalli	B.	4.604 / 38.3	2.142 / 17.8	2.948 / 24.5	-
	S.	1.693 / 14.0	2.525 / 21.0	2.751 / 22.9	-
Damsite	B.	3.237 / 26.9	2.671 / 22.2	2.671 / 22.2	0.525 / 4.3
	S.	1.044 / 8.8	1.269 / 10.5	1.148 / 9.5	0.206 / 1.2

(During August and September)

		30 mm	40 mm	45 mm	50 mm
Damsite	B.	0.331 / 2.2	0.509 / 3.3	0.721 / 4.8	0.634 / 4.2
	S.	0.227 / 1.5	0.553 / 3.7	0.489 / 3.2	0.266 / 1.7

B = bottom , S = surface.

Uniformly matched surface and bottom nets for six months from October 1965 to March 1966 indicate undisputable higher yield by bottom set gill nets (table 27) . The following also gives a clear picture.

	Surface		Bottom	
	No.	Wt. (kg)	No.	Wt. (kg)
Mudalighatti	102	54.50	257	100.40
Sovinahalli	120	26.88	142	48.45
Hampasagar	69	16.28	119	41.72
Katharki	62	46.02	137	29.09
Tambrahalli	121	26.23	188	44.84
Karkihalli	52	10.99	63	14.67
Damsite	132	29.93	246	78.66
Total	718	210.73	1152	358.53

The average catch per day (in kgs) and average catch per unit area (in grams per m^2) are given in table 26.

It is apparent that the number of fish caught in bottom nets increased by 60.4% and by weight 70.2%, pooling all values. Of the total number of fish caught 38.4% are referable to surface and 61.6% to bottom by numbers and 36.9% to surface 63.1% in bottom nets by weight.

Selectivity of nets:

Gill nets are known to be highly selective to the shape and sizes of fishes, there being both an upper and lower limit in sizes of fish caught. Improper hanging of webbing on the head rope absence of sinkers or even of a bottom rope (as in several Rangoon nets) etc., contribute poorer catches. Further, majority of catfishes are entangled by their spines rather than gilled like carps. Even amongst carps, hard spined species like Puntius sarana, Tor spp., etc., are entangled and get enmeshed rather than gilled. Ranges in sizes of catfish caught are wider compared to those of carps as both small and large catfishes are caught in almost all nets.

Table 27

Percentage composition by weight in surface and bottom nets at 7 centres

(between Oct. 65 & Mar. '66)

Species	SURFACE SETS No. of fish	Wt. in kg	Percentage	Species	BOTTOM SETS No. of fish	Wt. in kg	Percentage.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MUDALIGHATTI :							
P.dobsonii	16	7.500	13.8	S.childrenii	71	38.400	38.2
P.pulchellus	1	7.000	12.9	P.kolus	44	16.940	16.9
O.vigorsii	49	6.930	12.7	O.vigorsii	69	9.310	9.3
S.childrenii	20	6.910	12.7	Tor spp.	2	5.210	5.3
L.fimbriatus	10	6.030	11.1	W.attu	3	5.200	5.2
B.bagarius	2	6.000	11.0	P.pulchellus	1	5.250	5.2
P.kolus	19	5.130	9.4	L.fimbriatus	8	3.560	3.6
P.sarana	19	2.780	5.1	P.taakree	15	3.370	3.4
P.taakree	10	1.650	3.0	P.dobsonii	4	2.910	2.9
C.mrigala	1	1.000	1.8	M.seenghala	3	2.300	2.3
L.calbasu	3	0.910	1.7	M.aor	5	2.000	2.0
M.seenghala	2	0.850	1.6	P.sarana	14	1.970	2.0
O.bimaculatus	5	0.640	1.2	R.pavimentata	6	1.680	1.6
W.attu	2	0.480	0.9	L.calbasu	6	0.900	0.9
L.bata	1	0.270	0.5	M.armatus	1	0.650	0.6
M.aor	1	0.200	0.4	O.bimaculatus	5	0.550	0.5
C.reba	1	0.120	0.2	C.reba	1	0.200	0.2
	162	54.400	100.0		257	100.400	100.0

Contd..Table 27

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SOVINAHALLI :							
P.kolus	24	9.550	35.6	S.childrenii	18	15.210	31.5
O.vigorsii	47	4.285	16.0	P.kolus	21	6.020	12.4
P.taakree	17	3.510	13.3	M.aor	8	5.340	11.0
L.fimbriatus	5	2.680	10.0	L.fimbriatus	9	5.190	10.8
M.aor	4	2.340	8.7	R.pavimentata	17	4.290	8.8
P.dobsonii	2	1.380	4.8	O.vigorsii	37	4.090	8.4
O.bimaculatus	6	1.050	3.9	M.seenghala	4	3.400	7.0
S.childrenii	3	1.000	3.7	P.dobsonii	6	1.880	3.9
P.sarana	6	0.630	2.3	L.calbasu	4	1.010	2.1
L.calbasu	1	0.150	0.5	P.sarana	9	0.920	1.9
O.pabo	1	0.150	0.5	O.bimaculatus	3	0.450	0.9
M.seenghala	1	0.080	0.3	P.taakree	3	0.250	0.5
R.pavimentata	1	0.060	0.2	P.pulchellus	1	0.200	0.4
W.attu	2	0.060	0.2	W.attu	2	0.200	0.4
	120	26.885	100.0		142	48.450	100.0
HAMPASAGAR :							
P.kolus	14	4.650	28.5	M.punctatus	1	14.000	33.5
O.vigorsii	27	3.330	20.4	P.kolus	27	7.690	18.6
C.mrigala	1	2.000	12.3	O.vigorsii	44	5.340	12.8
L.fimbriatus	4	1.440	8.8	L.fimbriatus	6	2.630	6.3
P.sarana	8	1.430	8.8	W.attu	6	2.580	6.2
M.aor	1	3.300	8.0	R.pavimentata	1	2.430	5.8
O.bimaculatus	4	0.690	4.2	O.bimaculatus	7	1.580	3.8
P.taakree	5	0.660	4.2	P.sarana	12	1.560	3.7
C.reba	2	0.320	2.0	P.dobsonii	3	1.280	3.1

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
S.childrenii	2	0.250	1.5	S.childrenii	2	1.060	2.5
R.pavimentata	1	0.210	1.3	M.aor	2	0.570	1.4
				P. aakree	60	5.560	1.3
				L. albasu	1	0.390	0.9
				M. avasius	1	0.050	0.1
	69	16.280	100.0		119	41.720	100.0
KATHARKI :							
C.catla	1	19.000	4.2	O. igorsii	73	10.740	35.8
W.attu	1	9.000	19.6	L. imbriatus	20	6.260	20.9
S.childrenii	11	7.150	15.5	W. ttu	4	3.070	10.2
L.fimbriatus	5	2.570	5.6	C. eba	10	2.120	7.0
O.vigorsii	27	3.430	7.5	P. olus	7	1.630	5.4
C.mrigala	1	1.800	4.0	M. or	4	1.260	4.2
P.kolus	4	0.950	2.1	M. eenghala	3	1.200	4.0
P.sarana	6	0.750	1.6	S. ildrenii	4	1.030	3.4
M.aor	1	0.600	2.3	P. arana	4	0.750	2.5
C.reba	2	0.400	0.9	P. bsonii	2	0.710	2.4
N.khavalchor	1	0.140	0.3	P. akree	3	0.600	2.0
O.bimaculatus	1	0.130	0.2	L. ta	1	0.400	1.3
P.taakree	1	0.100	0.2	N. topterus	1	0.200	0.7
	62	46.020	100.0		137	29.990	100.0

Contd..Table 27

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TAMBRAHALLI :							
S.childrenii	15	7.430	28.3	O.vigorsii	88	11.420	15.4
O.vigorsii	69	6.700	25.5	S.childrenii	25	11.010	24.4
L.fimbriatus	4	2.340	9.0	W.attu	4	4.960	11.1
M.seenghala	3	2.090	8.0	Mystus aor	7	4.090	9.1
P.dobsonii	1	1.500	5.7	P.kolus	25	4.020	8.9
M.aor	2	1.450	5.5	M.seenghala	4	3.530	5.8
P.sarana	10	1.300	5.0	P.taakree	11	2.370	5.3
P.taakree	8	1.380	5.5	L.fimbriatus	5	2.070	4.6
W.attu	1	0.680	2.6	P.sarana	12	1.370	3.0
P.kolus	5	0.530	2.0	L.calbasu	1	0.370	0.8
L.calbasu	1	0.440	1.7	P.dobsoni	1	0.320	0.7
N.notopterus	1	0.220	1.2	N.notopterus	3	0.250	0.5
O.bimaculatus	1	0.130	0.5	N.khavalchor	1	0.070	0.2
				O.bimaculatus	1	0.070	0.2
	121	26.230	100.0		188	44.940	100.0
KARKIHALLI :							
S.childrenii	9	3.200	29.1	O.vigorsii	28	4.770	32.5
O.vigorsii	14	1.230	11.1	S.childrenii	6	2.710	18.4
P.kolus	5	1.165	10.6	P.taakree	8	1.680	11.5
P.taakree	7	1.000	10.0	P.kolus	5	1.340	9.2
M.aor	2	1.100	10.0	R.pavimentata	3	1.290	8.8
L.calbasu	2	0.800	7.2	P.sarana	8	1.230	8.4
P.sarana	8	0.890	8.0	W.attu	1	0.700	4.8
W.attu	1	0.600	5.5	L.calbasu	1	0.350	2.4
C.catla	1	0.600	5.5	C.reba	1	0.280	1.9
O.bimaculatus	2	0.220	2.0	M.aor	1	0.170	1.1
P.pulchellus	1	0.110	1.0	L.fimbriatus	1	0.150	1.0
	52	10.995	100.0		63	14.670	100.0

Contd..Table 27

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DAMSITE :							
P.kolus	35	11.345	38.8	L.calbasu	13	12.315	16.6
W.attu	2	4.700	15.7	M.seenghala	12	9.640	12.2
P.sarana	30	3.890	13.0	M.aor	17	9.146	11.6
S.childrenii	4	2.540	8.5	R.pavimentata	28	8.160	10.0
O.vigorsii	31	2.395	8.0	P.kolus	24	7.517	9.5
L.calbasu	1	1.470	5.0	O.vigorsii	55	6.077	7.7
P.taakree	12	1.436	4.8	P.sarana	40	4.430	5.6
L.bata	3	0.443	1.5	C.catla	1	4.000	5.1
L.fimbriatus	1	0.420	1.4	L.fimbriatus	7	3.970	5.0
M.seenghala	1	0.250	0.8	W.attu	3	3.820	4.8
M.aor	1	0.210	0.7	Tor spp.	3	3.290	4.2
Tor spp.	1	0.150	0.5	P.taakree	11	2.150	2.7
N.khavolchor	2	0.130	0.4	S.childrenii	4	1.500	1.9
Oxygaster spp.	3	0.114	0.4	P.dobsonii	1	0.650	0.8
O.neilli	2	0.090	0.3	L.bata	3	0.370	0.5
O.bimaculatus	3	0.290	0.1	M.cavasius	6	0.350	0.4
				O.neilli	6	0.300	0.4
				Oxygaster spp.	4	0.250	0.3
				O.bimaculatus	3	0.260	0.3
				T.sandkhol	1	0.200	0.2
				N.khavalchor	3	0.120	0.1
				L.potail	1	0.150	0.1
	132	29.993	100.0		246	78.665	100.0

TABLE 28

Number & Weight per net day and catch per unit area of surface and bottom sets – at 7 fishing centres.
(from October 1965 to March 1966)

SURFACE							BOTTOM						
Mesh in mm	Total No. of fish	Total Wt. in kg	No. of net day	No. per net day	Wt. per net day in kg	Catch per Unit area in kg	Mesh in mm	Total No. of fish in kg	Total Wt. in kg	No. of net day	No. per net day	Wt. per net in kg	Catch per Unit area in kg
1	2	3	4	5	6	7	8	9	10	11	12	13	14
MUDALIGHATTI :													
30	83	12.060	115	0.7	0.105	0.0007	30	141	27.430	115	1.2	0.238	0.0015
40	28	5.420	115	0.2	0.047	0.0003	40	41	15.420	115	0.4	0.134	0.0009
45	24	6.880	115	0.2	0.060	0.0004	45	36	20.220	115	0.3	0.175	0.0011
50	17	8.150	115	0.1	0.071	0.0004	50	34	25.040	115	0.3	0.217	0.0014
65	9	14.890	115	–	0.129	0.0008	65	3	2.040	115	–	0.018	0.0001
80	1	7.000	115	–	0.060	0.0004	80	1	5.250	115	–	0.046	0.0003
							100	1	5.000	115	–	0.043	0.0003
SOVINAHALI :													
30	49	4.485	104	0.5	0.043	0.0002	30	64	7.920	104	0.6	0.076	0.0004
40	31	5.700	104	0.3	0.055	0.0003	40	39	10.720	104	0.4	0.103	0.0007
45	28	7.600	104	0.3	0.073	0.0004	45	21	11.220	104	0.2	0.108	0.0007
50	7	4.610	104	–	0.044	0.0003	50	13	12.280	104	0.1	0.118	0.0008
65	5	4.490	104	–	0.043	0.0003	65	3	4.260	104	–	0.041	0.0002
							80	2	2.050	104	–	0.020	0.0001
HAMPASAGAR :													
30	31	3.470	82	0.4	0.043	0.0003	30	45	5.220	82	0.5	0.064	0.0004
40	23	4.120	82	0.2	0.050	0.0003	40	26	6.700	82	0.3	0.082	0.0005
45	13	3.950	82	0.1	0.048	0.0003	45	27	5.990	82	0.3	0.073	0.0005
50	3	1.440	82	–	0.018	0.0001	50	20	9.810	82	0.2	0.120	0.0008
65	2	3.300	82	–	0.040	0.0002	90	1	14.000	82	–	0.170	0.0011

Contd..Table 28

1	2	3	4	5	6	7	8	9	10	11	12	13	14
KATHARKI :													
30	33	4.210	71	0.5	0.059	0.0004	30	55	9.080	71	0.9	0.127	0.0008
40	11	3.210	71	0.1	0.045	0.0003	40	37	7.910	71	0.5	0.111	0.0007
45	8	2.900	71	-	0.041	0.0002	45	24	6.480	71	0.3	0.091	0.0006
50	2	1.800	71	-	0.025	0.0001	50	11	6.520	71	0.1	0.092	0.0006
65	5	5.900	71	-	0.083	0.0005							
80	1	19.000	71	-	0.268	0.0077							
90	1	9.000	71	-	0.127	0.0008							
TAMBRAHALLI :													
30	86	8.870	82	1.05	0.108	0.0007	30	123	15.480	82	1.5	0.189	0.0012
40	17	4.980	82	0.2	0.061	0.0004	40	31	8.760	82	0.4	0.107	0.0007
45	9	4.530	82	0.1	0.055	0.0003	45	23	10.340	82	0.3	0.123	0.0008
50	6	4.100	82	-	0.050	0.0003	50	10	8.840	82	0.1	0.108	0.0007
65	3	3.750	82	-	0.046	0.0003	90	1	1.520	82	-	0.089	0.0001
KARKIHALLI:													
30	35	4.055	74	0.5	0.055	0.0003	30	31	4.160	74	0.4	0.056	0.0004
40	8	2.200	74	1.0	0.030	0.0002	40	16	3.450	74	0.2	0.047	0.0003
45	8	4.140	74	-	0.056	0.0004	45	10	3.970	74	0.1	0.054	0.0003
50	1	0.600	74	-	0.008		50	6	3.090	74	-	0.042	0.0003
DAMSITE :													
30	86	10.360	454	0.2	0.023	0.0001	30	114	13.859	454	0.3	0.031	0.0002
40	24	6.400	454	-	0.014	-	40	68	20.510	454	0.1	0.045	0.0003
45	14	4.170	454	-	0.009	-	45	33	10.835	454	-	0.024	0.0001
50	6	4.830	454	-	0.011	-	50	26	16.911	454	-	0.037	0.0002
65	1	1.470	454	-	0.003	-	65	3	9.050	454	-	0.020	0.0001
80	1	2.700	454	-	0.006	-	90	1	3.500	454	-	0.008	-
							100	1	4.000	454	-	0.009	-

Surface set = 30 mm, 40 mm, 45 mm, 50 mm, 65 mm, 80 mm and 90 mm.

Bottom set = 30 mm, 40 mm, 45 mm, 50 mm, 65 mm, 80 mm, 90 mm and 100 mm.

Table 29

Meshwise and specieswise number of fish caught and their size ranges during 1964 & 1965

Mesh size in mm.	1964 Nos.	1964 Size range in mm.	1965 Nos.	1965 Size range in mm.
(1)	(2)	(3)	(4)	(5)
P. kolus :				
30	-	-	152	100-380
35	-	-	125	181-420
40	822	181-420	480	181-420
45	222	181-420	351	221-460
50	80	261-460	80	261-420
60	-	-	2	341-380
65	1	301-340	-	-
P. sarana :				
30	-	-	86	110-290
35	-	-	58	110-350
40	124	190-320	66	171-320
45	29	200-350	23	201-320
50	2	231-320	15	201-290
65	3	261-290	-	-
P. dobsoni :				
30	-	-	4	200-290
35	-	-	3	231-410
40	91	200-478	41	231-470
45	18	231-440	35	200-500
50	23	231-440	32	231-500
60	2	321-410	3	381-530
65	1	478-	4	381-560
75	-	-	1	531-560
80	4	351-470	1	681-710
90	3	351-440	11	475-
105	1	378-	-	-
115	1	411-440	1	531-560
120	-	-	2	651-743

Contd..Table 29

(1)	(2)	(3)	(4)	(5)
Tor spp.				
30	-	-	2	140-260
35	-	-	1	261-280
40	2	261-380	10	231-410
45	1	321-351	3	321-380
50	-	-	3	351-440
55	-	-	3	351-560
80	1	725	-	-
95	-	-	1	471-500
105	3	865-1000	-	-
115	1	870	-	-
130	-	-	1	531-560
155	2	810-1021	-	-
L.calbasu :				
3	-	-	12	200-230
40	18	261-500	8	200-440
45	4	230-380	3	291-350
50	3	321-440	7	291-440
60	1	501-530	1	501-530
65	1	471-500	-	-
80	1	501-530	-	-
85	-	-	2	590-647
115	-	-	1	590-610
L.fimbriatus :				
30	-	-	5	200-380
35	-	-	8	231-320
40	86	230-440	84	231-530
45	28	261-410	59	231-500
50	36	261-560	50	261-560
60	-	-	12	351-530
65	2	441-560	1	411-440
80	6	441-560	1	531-590
85	-	-	1	531-590
90	2	606-694	-	-
105	-	-	1	561-590
115	1	725-	5	471-560

Contd.. Table 29

(1)	(2)	(3)	(4)	(5)
C.catla:				
35	-	-	2	291-350
40	7	230-440	9	260-380
45	-	-	3	291-380
50	2	381-470	3	291-410
65	-	-	2	351-380
80	2	509-670	-	-
95	-	-	1	1000-
120	-	-	1	600-
125	2	904-1010	-	-
155	7	710-1057	-	-
O.vigorsii :				
30	-	-	409	70-310
35	-	-	158	101-370
40	270	161-400	470	131-400
45	29	191-370	157	131-370
50	6	191-400	75	131-400
N.notopterus :				
30	-	-	7	200-320
35	-	-	22	231-350
40	28	200-320	3	261-320
45	7	261-320	1	321-350
50	7	261-350	-	-
M.seenghala:				
30	-	-	5	280-480
35	-	-	2	321-760
40	36	309-836	39	321-720
45	18	401-760	26	280-805
50	29	401-836	28	401-785
60	-	-	5	561-760
65	3	601-720	3	401-760
80	5	681-950	2	561-680
95	-	-	2	641-680
105	3	681-1070	-	-
115	2	721-1025	3	521-680

Contd..Table 29

(1)	(2)	(3)	(4)	(5)
M.aor:				
30	-	-	11	200-640
35	-	-	4	361-440
40	22	320-760	31	200-560
45	7	481-720	35	321-760
50	19	441-720	39	321-760
60	-	-	2	441-640
65	1	561-600	4	601-924
80	1	521-600	1	-
95	-	-	1	441-480
105	-	-	1	521-560
W.attu :				
30	-	-	6	241-640
35	-	-	17	241-440
40	9	361-680	48	241-680
45	21	441-760	28	174-780
50	12	441-760	32	281-780
65	10	481-955	3	401-720
80	3	561-940	1	741-780
90	-	-	3	441-640
95	-	-	1	741-780
105	3	521-640	2	681-875
115	1	561-600	-	-
125	8	601-800	1	721-740
140	1	401-440	-	-
155	1	721-760	-	-
S.childrenii :				
30	-	-	46	230-430
35	-	-	16	281-430
40	135	230-610	159	230-580
45	67	230-610	125	230-730
50	42	230-580	86	230-680
60	-	-	12	431-630
65	4	431-530	3	481-680
80	1	431-650	5	381-680
105	1	381-430	-	-
115	2	431-630	-	-
125	2	481-580	-	-

Contd.. Table 29

(1)	(2)	(3)	(4)	(5)
P.taakree				
30	-	-	59	130-380
35	-	-	3	231-380
40	27	130-430	60	130-430
45	7	181-488	14	181-480
50	9	130-380	4	281-430
65	1	181-230	-	-
80	-	-	1	381-430
85	-	-	13	281-380

Specieswise, the following observations can now be made on the data obtained and presented in tables 28 & 29. It is to be pointed out that 30 and 35 mm (bar) nets were not employed in 1964.

Puntius kolus :

Nets of 40 mm (bar) were found highly effective for this species, which took fish ranging from 181 to 460 mm in total lengths. 30 mm bar net showed a lower 100 and an upper of 380 mm size limit. 35 mm bar mesh was equally effective. Sizes of fish caught were all adults.

Puntius sarana :

The marketable sizes of 205 to 275 mm length specimens are common in the reservoir. 346 mm was the maximum size recorded. 30, 35 and 40 mm bar nets were efficient in capturing this species, ranging between 110 and 320 mm.

Puntius dobsonii :

270 to 510 mm (t.l.) sized fish frequently caught in all gill nets enter into commercial catches even though the species is a scarce form in the reservoir. Maximum size attained by this species is 810 mm. In experimental gill net catches, 200 to 500 sized fish were caught more effectively in 40, 45 and 50 mm bar nets. Majority of specimens were immature or maturing.

Tor spp. :

Occurrence of mahseers in general catches is poor. Both 40 and 50 mm bar nets proved more successful for juvenile specimens of between 231 and 410 mm. Larger specimens of 865 to 1021 mm have been obtained in 105 to 155 mm bar nets at Hampasagar indicating _Tor_ to move mainly in shallower areas above in preference to deeper zones.

Labeo calbasu :

This fish is infrequent in commercial catches where 270 to 550 mm lengths were recorded even though the fish attains 750 mm in length. Specimens of 200 to 400 mm length/range were recorded in 40,45 and 50 mm bar nets.

Labeo fimbriatus :

This fish contributes considerably (by weight) to commercial catches ranging from 270 to 670 mm in maximum length 790 mm.). Nets of 40, 45 and 50 efficiently caught specimens between 230 and 560 mm.

Catla catla :

Generally 40,45 and 50 mm mesh nets caught this fish grown to 260 to 410 mm in total lengths. Higher meshed nets of 125 to 155 mm were effective in capturing stray specimens of 904 to 1057 mm. The gap between these two sizes indicates the descripancy in stocked fish availability as intermediate sizes were absent.

Osteobrama vigorsii :

In commercial catches 215 to 325 mm lengths were recorded, maximum size attained being 395 mm. 30, 35, 40 and 45 mm bar nets were found effective for this species which generally was entangled by its dorsal spine. Size of 110 to 370 mm were caught. 30 and 40 mm nets were more efficient.

Notopterus notopterus :

35 and 40 mm nets were effective in catching this species of a size range from 231 to 320 mm in the reservoir.

Mystus seenghala :

This is the most important catfish of the reservoir in commercial catches, 410 to 1030 mm lengths being common. A maximum length of 1300 mm is attained by this species. 321 to 836 mm length specimens were frequently caught during experimental fishing. It is observed that 40 mm bar nets generally captured 309-836 mm, 45 mm nets- 401 to 805 mm and 50 mm nets 561 to 760 mm sized specimens more efficiently even though almost all nets from 30 to 115 mm served to catch the species at one time or the other. 95, 105 and 115 mm nets caught specimens of 641 to 1025 mm in size. Adult sized specimens however were very few.

Mystus aor :

Being next to M. seenghala in catches, 310 to 770 mm lengths were generally observed in commercial landings. 1100 mm is the maximum length attained by this species; 40, 45 and 50 mm nets proved effective between 200 and 700 mm lengths, Adults of the species were not seen during operations.

Wallago attu :

470 to 790 mm size group dominated the commercial catches though 1250 mm length is attained by the species. 40,45 and 50 mm nets were efficient and selective for size range of 241 to 780 mm. Smaller specimens of 241 to 440 and occasionally even up to 640 mm were caught in 30 and 35 mm nets. 125 mm net caught 601 to 900 mm group. Possessing somewhat a flat head, and spines on the fins, specimens were recorded haphazardly in various meshed nets.

Silonia childrenii:

270 to 510 mm size groups dominated landings in general, maximum recorded being 735 mm. 40, 45 and 50 mm nets caught very effectively 230 to 680 mm sized specimens. 40 mm net was more efficient than others capturing maximum number ranging between 230 and 610 mm in sizes. 30 and 35 mm net caught 230 to 430 mm sized specimens as well. No specimens considered young, were found.

Table 30

Sex and stages of maturity of important carps and cat-fishes caught in experimental gill nets during 1965.

(A comparision of relative numbers of each species and sex ratio as well ratios in maturity stages can be obtained from the table)

Species	Maturing (I & II)		Mature (III, IV & V)		Spawning/spent (VI & VII)		Total	
	♂	♀	♂	♀	♂	♀	♂	♀
P.kolus	294	255	53	156	57	127	404	632
P.sarana	50	132	11	58	1	2	62	192
P.dobsoni	50	67	1	4	2	1	53	72
Tor spp.	7	10	–	1	–	1	7	12
L.calbasu	9	17	2	3	–	4	11	24
L.fimbriatus	128	106	–	4	2	–	130	110
C.catla	12	1	–	–	1	–	13	1
O.vigorsii	134	560	39	235	6	17	179	812
N.notopterus	12	20	–	5	–	–	12	25
M.seenghala	53	64	7	6	–	–	60	70
M.aor	39	65	11	16	–	1	50	82
W.attu	41	76	10	11	–	2	51	89
S.childrenii	85	311	10	11	8	28	103	350
P.taakree	40	66	3	18	2	6	45	90

Pseudentropius taakree :

205 to 385 mm sizes were found in commercial catches even though the species attains at least 430 mm. 30 and 40 mm nets proved of value in capturing the species, which ranged between 130 and 430 mm during experimental fishing.

Sex and maturity of Fishes caught in Experimental Nets:

Both in carps and catfishes females dominated over the males. As can be seen from the table 30, representation of all stages of maturity amongst P.kolus, P.sarana, O.vigorsii etc., indicate that these fishes are established within the reservoir conditions as already stated. Maturing specimens of P.dobsonii, L.fimbriatus, L.calbasu, Tor spp and C.catla, but meagre number of mature ones show that these fishes escape into the main river for breeding. Even the few recorded mature specimens are only from Zone I (centre-A) and Zone II (centre-B & C) and at no time fully mature specimens of P.dobsonii, L.fimbriatus, L.calbasu, Tor spp. and C.catla were even recorded in the open reservoir (Zones III and IV). These findings confirm observations mentioned in Part II.

In gill net catches maturing stages of M.seenghala and M.aor though caught frequently, no mature specimens were ever caught in the main reservoir, the few specimens recorded being from Zones I and II. These two major catfishes were found escaping into the river above much earlier in March - April (before monsoon) months for breeding. Hence representations of mature specimens are meagre in number. Mature specimens of W.attu, S.childrenii and P.taakree also migrate into the river for breeding. Only maturing specimens were recorded in gill nets during fishing operations in the main reservoir and stray mature specimens in the riverine Zone I and II. Particularly mature S.childrenii were even rarer in riverine zones, than all other species.

Conclusions:

i. There is a consistent parallel between the commercial and present experimental catches in gill nets. Alivi, though indicating almost the same size ranges with more of smaller sized specimens, however indicated a dominant catfish population. The gill nets whether surface or bottom as used, do not present a picture of true fish population.

ii. No depthwise distribution of fish has been observed even though all the species appear alike in composition between surface and bottom nets. Catches alone are consistently higher in bottom set gill nets. Movements of fish or their groupings do not appear to influence catchability of gill nets at various regional centres.

iii. More number of larger sized fishes are caught generally in the upper stretch rather than the open waters of the reservoir.

iv. During early flood incursion, most of the forms are found ascending the river, hence catches become richer in the stretch close to the backwash.

v. Majority of species caught are juvenile and maturing forms rather than older residents of the reservoir. Following flooding, larger fish - Tor spp., Puntius pulchellus, P.dobsoni Labeo fimbriatus and Wallago attu are caught during September-December; some large sized Catla also are then found. These are obviously brought into the reservoir with the floods from the upper riverine stretch as such large specimens even during the height of fishing season are few or absent.

vi. Preferred mesh sizes are 40 to 60 mm (bar) at all times and larger meshed 90 to 155 mm in post monsoon months for capturing available species. 30 and 35 mm (bar) nets capture mainly Puntius kolus and similar sized fishes in numbers rather than by weights.

vii. Winds, high waves and turbidities do not appear to disturb areas of fish distribution or their depthwise occurrance. Winds and waves between July and September however impede gill net operations. Turbidities caused by wind action between July and September, disappear from October onwards. Moreover, many larger fish are driven towards shallower margins mainly for feeding and even if caught in strays, fetch good price.

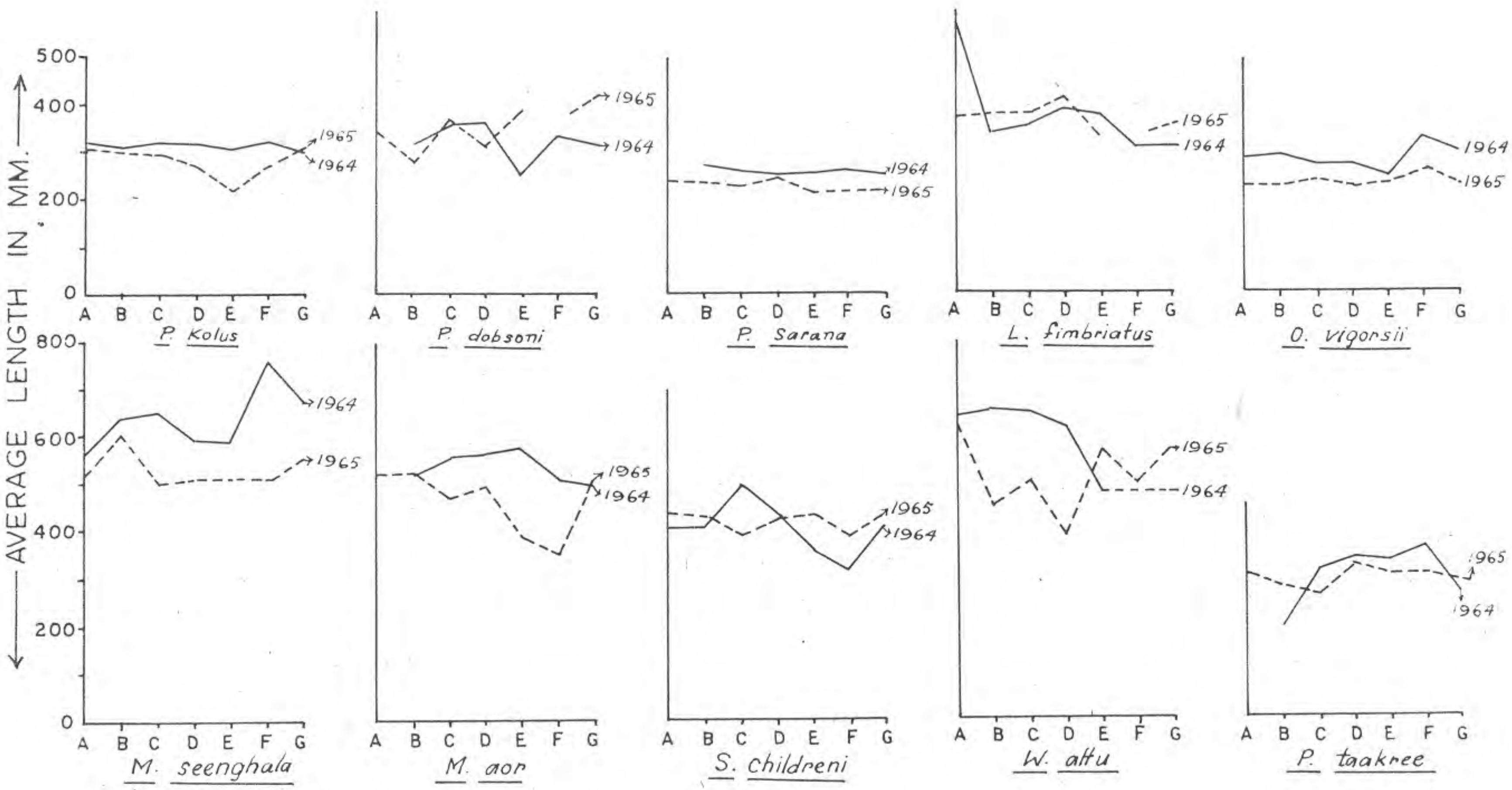


FIG. 13.

AVERAGE SIZE DISTRIBUTION FOR THE YEAR 1964–'65 AT 7 CENTRES.

viii. There is a declining trend in average sizes of fish caught and their weights between 1964 and 1965 (fig.13) in experimental fishing nets. Commercial catches also show a declining trend in lengths and weight of several individual fishes.

PART V

ASSESSMENT, FINDINGS AND RECOMMENDATIONS

FERTILITY AND FISH-FOOD ORGANISMS

The great Lakes in the N.American continent and those in tropical Africa, present features in fertility quite unlike those of storage reservoirs. Comparisons can be made mainly between multiple purpose reservoirs like those under the T.V.A and Indian reservoirs. Studies are directed towards production of sport fish in advanced countries but in India such storage reservoirs have to produce food fish and the cost of production should be reasonable to keep price of fish low. Greatly fluctuating reservoir levels from the monsoon filled high levels to the gradually shrinking summer levels is a regular feature in India. The tropical weather conditions augment conditions for the better as sunshine and temperatures being generally of a high order, there is more energy storage and basic photosynthetic and bacterial activity than in temperate zones.

Morphometric factors such as a more shallow basin in spite of reservoirs large size and an unusually long periphery, edaphic factors that supply dissoved nutrients from a varied catchment of 24,000 sq km covering forests and riparian lands leaching of minerals from mainly rocky river bed and consistently higher ranges of temperature (23.1-31.5°C) as well as long hours of sunshine are some factors operating favourably within the Tungabhadra reservoir. Production capacities of N.American lakes are related to lake dimensions as well as mean depths; larger the dimensions and greater the depths, production of fish food and hence fish production steeply decreases.

It is known that 35% of the littoral zone containing only 6% of water, produces majority of fish food needed in a lake within tropical conditions. Within the Tungabhadra reservoir the shallow water region under 10 feet of water that can produce the maximum food, ranges from 18.3 to 30.6% of the total water area over the year except when water reaches 1590 feet level. Only later there is a sharp decline in available shallow area to about 15.6%. In the prevailing tropical and clear water conditions even 40 to 50 feet depths as in the Tungabhadra reservoir, are known to be very rich. Production of water area below 5 and 10 feet depths remains constant (table 3) presenting always biologically and active area to maintain density of invertebrate food organisms sufficiently high. Desiccation of marginal aquatic flora and fauna occurs once the reservoir level begins to lower. The high wind action and marginal waves further add to the destruction. The higher water temperatures in the littoral zone as noted in April-May, also add to the killing of molluscan fauna. While there is little vascular vegetation of a permanent submerged kind and the few forms present are seasonally destroyed, the faunistic elements constituted of various insect groups (inclusive of chironomid larvae), Oligochaetes and molluscs, are able gradually to migrate or move downwards to their optimum levels of preferance with the fall in level of 3 to 4 inches (7.0-10.0 cms.) per day. Further, nutrient elements in the soft deposited silt and alluvium are already shown to be high due to their allochthonous nature. These deposits are subjected to considerable bacterial activity coincident to increasing temperatures (January onwards) but sessile microvegetation, diatoms, chlorophyceae etc. then multiply at depths of between one and two meters. These derive their nutrients especially nitrates and phosphates from the substrate which is already shown to be quite rich (17% organic contents). The prevailing winds from February with considerable wave action increase by May-June, all the time leaching the littoral zone of nutrients and salts and dislodging substratal sessile organisms which then enter into plankton groups.

Basic productivity levels are well maintained in the reservoir except perhaps in the transition period of flooding and fast increasing levels between June and July.

In the Tungabhadra reservoir, power generation and irrigation needs are met by withdrawing 9500 to 13500 cusecs of water continuously. Hence the reservoir is constantly being flushed at the bottom between 50 and 80 feet below the maximum water level (1630 fee t). Theoretically by constant exchange of water, there should be no build up of storage of fertility. But lower fertility can occur in deep ravine reservoirs whose shore and volume developments are low unlike the shallow sprawling Tungabhadra reservoir. This constant flushing and replacement of water has brought about a high degree of oligotrophic condition. Water below the dam has similar characteristics as the main reservoir in physico-chemical and even plankton features. Such flushing effects undoubtedly create a constant loss of nutritional ingredients, salts and plankton. But even as such losses take place, there is constant replenishment from the main river to the reservoir as at no time any unusual fall in nutritional elements and plankton is recorded. The exposure areas, constant mineralisation, marginal higher temperatures, wave actions etc., aid in the release of nutrients from deposited layers continuously.

The dominant molluscan fauna while dead, adds considerably to the calcium carbonate components in soil deposits which may become available under certain conditions to the overlying waters as bound carbondioxide. This in turn creates a very favourable medium for cladocerans.

The above levels of fertility are much higher than those prevailing in Bhavanisagar or Mettur reservoirs both of which edaphically and in size, contours and depths are unfavourably situated than the Tungabhadra reservoir. Abundance of catfish presupposes abundance of forage forms. When catfish occur greatly in catches (January to June), the suspected forage species are not in great abundance. Majority of catfishes are small being 0 + 1 year classes. Catfishes except Wallago feed also upon insects and molluscs. During receding waters and with the gradual elimination of most young carps seasonally produced forage fishes are eliminated. This compels the catfish to switch over to alternate food - e.g. insects and molluscs between January/ February and June.

The prey population remains high in the catfish growing period i.e. between July and December as shown by young fish studies. The smaller preys - Cirrhina reba, Oxygaster spp. Aspidoparia spp., several small Puntius spp. (minnow carps), and prawns - Leander spp. are found in great abundance as described, soon after the monsoon when reservoir fills. As forage fishes are restricted to littoral and subsurface zones in the reservoir, they find sufficient food all the time; feeding upon detritus, plankton etc., they do not compete with food of young catfish, which outgrow them soon. Most forage fish do not grow out of their class, and those that grow, subject themselves as prey because their survival is now shown to be poor. Several at least have periodic spawning multiplying even as late as December. There are 4 catfishes and 17 small carp and minnow species that form prey for catfishes feeding at various food niches, possessing alternate feeding habits. This is peculiar to the Tungabhadra reservoir and perhaps to several other reservoirs in India. While prey population remains high between July and December and consists of several undesirable species the balance gets upset by January /February when predators take over with lowering water levels. Catfishes within the reservoir do not exclusively depend upon minnows and other carps as evidenced by absence of any starved and stunted forms. Factors such as sudden draw-downs, destruction or failure of fish food organisms to reproduce, abrupt increases in catfish populations etc are not observed in the Tungabhadra reservoir to impede production of food for carps.

Recommendations:

There is no need for any measures which may further add to basic fertility. Artificial fertilisation of the creeks and bays or planting by aquatic vegetation will only hasten siltation; hence any move to increase fish food production should be proceeded with caution in a storage reservoir. However, the following investigational research will be essential.

i. Computation of relationships between production of aquatic invertebrates and total production of fish; and feeding intensities by fish to assess optimum levels of feeding.

ii. Average standing stocks of invertebrates and related potential production of fish.

iii. The relative aspects of abundance and availability of food and growing season of fish should be correlated with the predator/prey ratio. Reproduction, growth and sizes of most invertebrates that form fish food have to be studied.

iv. Quicker volumetric and weight studies designed to assess production of plankton including 'tripton' i.e. nonliving particulate dead and disintegrating matter. As biological activities originate in bacterial activity upon both organic and inorganic matter, the nutrients deposited in the ooze as well as suspended in water have to be calculated.

v. Experimental work designed to assess food productivity may be taken up.

FISH PRODUCTION, COMPOSITION AND FISHING EFFORT

In the Tungabhadra Reservoir, considering production (1965) of 235 tonnes in a full water spread (or surface area) of 37,814 ha., hardly 6.2 kg/ha of fish are now computed to have been produced. This refers to the fish harvest and not its standing stock which may be 3 to 5 times more at any given time. As each alivi approximately encircles an area of 1.4 ha., considering actually examined field operations and landings (over 4-5 months of study) an average 13.4 kg/ha standing stock of fish is computed. In T.V.A reservoirs a standing crop of 100 lbs per acre is estimated of which only 30% can be removed i.e. of the 120 kg/ha standing crop, nearly 38 kg/ha is capable of removal. In the Tungabhadra reservoir, such estimates refer to the wide but long riverine stretch rather than the spreadout main reservoir Zone IV. Considering that only 30% of fish present is being now taken, at least 500 tonnes of fishes should be available in the reservoir for harvest each year. But if the catch composition were mainly fewer and consisted of fast growing carps feeding on detritus, plankton, aquatic weeds, molluscs and insects (Gangetic and other exotic carps) instead of the present slow growing medium carps with a vast number of catfishes and other predators, production should easily exceed 1000 tonnes per year. Because each predator is known to consume 5 times its body weight of other fishes to attain harvestable size, it is doubtful if such high productions can be attained in the Tungabhadra reservoir in the near future. Due to the overwhelming number of predators and easy escapement and annual recruitment from the river above, any effort for removal of predators and naturalise carps, will involve a long but purposeful programme.

As gill net catches in the main reservoir also increase at the time of low water in April-May, it is probable that only 25 to 35% of available fish are removed. Shrinkage of reservoir from 35690 ha (1630 msl) to low water so far attained of 10904 ha (1590 to 1587 msl) serves to concentrate the fish population which seek the shallow stretch of the river bed rather than the steeper depths of the Zone IV.

Only two or three reservoirs in India provide correct production figures. Mettur produces about 39 kg/ha and Bhavanisagar 12.7 kg/ha considering probably maximum surface levels. These catches refer mainly to major carps (75 to 80%) endemic to the river drainages as well as to stocked Gangetic carps and Cyprinus carpio. On the other hand by comparing the basic levels of fish food production, Tungabhadra reservoir is by far the riches of the three in nutritional elements. The basin also offers better topographical features with wide shallow areas or mud shoals in contrast to the rocky outcrops and higher mean depths of the Madras reservoirs. However, present higher fish production per/ha in many reservoirs is achieved by a long time stocking and conservation programme which produces quality fish unlike the coarse and wild forms within the Tungabhadra reservoir.

Exploitational rates can be intensified considerably in the Tungabhadra Reservoir, which in contrast to Mettur and Bhavanisagar can be fished in all 12 months. The reservoir has no obstructions that may affect fishing operations as in deeper and steeper reservoirs. Hardly 5 to 10% of the surface area shows some tree stumps situated in remote corners of the Zone IV (map 3). Even these areas are touched by surface gill net and long-lining operations. Hence exploitation of the deeper part of the reservoir (Zone IV) though not extensive, can still be practicable. Tungabhadra Reservoir is potentially more productive in fish and catchability of stock higher than many known reservoirs. There is a wide gap now itself between its gross productivity and net production since from investigations now concluded, there are no indications of depletion of fish by overfishing in the present level of abundances of exploitable stock. There has been no decline in yield per fishing effort and no downward trend in total production in the face of increasing fishing pressure.

Composition of major fishes within the reservoir is now known to be "rough" or coarse fishes rather than prime fishes, mainly consisting of residual and acclimatised catfishes from the river. Earlier when only gill net chatches were available for examination, a dominant carp population was surmised to be occupied by the ubiquitous Puntius kolus. But 'alivi' catches have now shown that catfishes actually dominate both by numbers and weights. The sharp contrast between gill nets and shore seines show opposite population structures due to selectivity of gill nets. Experimental fishing/ also indicate dominance by Puntius kolus and Silonia childrenii though both occur to a higher or lower degree at one zone or the other. /does not
Just because the present carp species are of not much utility or of prime quality, the catfishes which are in quantity are preferred to scaled forms. Considering dominance of catfishes and highly successful shore seine operations, it is obvious that the Tungabhadra reservoir is not a typical reservoir of its kind in India. Even though species composition of the Godavary and the Krishna rivers are almost similar, nowhere perhaps within reservoirs formed in their tributaries, catfish populations have completely taken over along with Osteobrama vigorsii. The Nizamsagar reservoir in the Godavary is dominated by Thynnichthys sandkhol which occurs only rarely within the Tungabhadra reservoir. Krishnarajasagar shows Wallago attu only along with Ompok bimaculatus. As Peninsular rivers hold varying species of fishes, each reservoir formed is capable of developing its own individualistic fish fauna. North Indian reservoirs cannot hold many varieties of catfishes

except *Wallago attu*, *Mystus aor* and *M.seenghala*, which however do not dominate carps in quantity and numbers.

Predominant catfish in the reservoir feed on the higher food chains i.e. other fishes, insects and molluscs. Carps on the other hand subsist on detritus and plankton. Hence there is an inherent loss in productivity. In the Tungabhadra reservoir, abundant forage fishes are available at least for greater part of the growing season of catfishes. In variety and numbers the reservoir is the richest though not in productivity. These catfishes attain fishable sizes earlier and reach maturing stages quickly. Most of them are short time breeders attaining maturity from one, as in the case of *Mystus cavasius* to two to three years in the case of *Pseudeotropius taakree*, *Silonia childrenii*, *Mystus seenghala*, *M.aor* etc. Further reproductive success of these forms is also quite high unlike fishes of the D.V.C and MP.reservoirs.

Recommended Measures :

Increasing commercial fish production, handling catches and creating favourable licensing, conservational and management practices, inducing permanent colonies of fishermen to come up, are still the administrative responsibility of the Tungabhadra Board authorities. However, the following measures appear to take precedence.

i. Setting up a central agency where fish landings are recorded after being collected from all over the reservoir by road or water transport, is a dire necessity as in the case of Nizamsagar, Mettur, Bhavanisagar, Govindsagar (Bhakra), D.V.C., and most other reservoirs in India.

ii. The reservoir is amenable for intense fishing activity almost throughout the year. Gill nets, shore seines, and longlines as at present can be intensified on a commercial scale. At a later stage, if any shoaling fishes come up, drift nets can be used. As submerged trees are few, expensive "tree cutting" programmes may not be necessary as even in the available space (90-95% of submergeable area) fishing can be intensified.

iii. It should be possible to design 'trap' nets suited to conditions in the reservoir to avoid constant shifting of fishing locations. Bush shelters and small net traps can also be tried. Use of any fish finders, electrical fishing methods, light fishing etc., may add to selectivity of sizes and species.

iv. Some protection to quality species of fish within the dead storage levels of the reservoir will be necessary by restriction imposed upon species, sizes, and number of fishing units allowed to operate during April-May months. Majority of fishes gather at the top water where shore seines can be operated and intense fishing selectively can be used for population or species control.

v. Eradication of as many catfishes as is possible by intensifying shore seine operations is essential. Even one or two outboard powered boats and longer alivi nets may increase operational effectiveness by encircling larger areas quickly.

vi. Recruitment of catfishes is now from the main river and its tributaries along with indigenous carps. The rivers above have to be studied further for fish species composition. It is obvious that catfishes present in the reservoir now, while attaining maturity escape into the main river and build up stocks. Similarly any stocked carps also escape into the river above. This annual escapement is in June-July with incoming flood waters when in the river above-some 20-25 km from centre A (Mudaligatti) Killekethas are known to be killing fish. The Tungabhadra authority has no control over such escapements. Observing a closed season for about a month, restriction of species and gear, will ensure better, self recruited stocks.

PROBLEMS OF FISH ESCAPEMENT AND MIGRATION RELATIVE TO THE RESERVOIR, CONNECTED RIVER AND CANALS.

River :

A major threat posed by mainstream reservoir dams is prevention of migratory fish from moving up and down. From studies made a few years ago as to the provision of fish ladders, lifts and fishways in Hirakud and in D.V.C dams, it was concluded that since there are migratory fishes forming a major fishery whose biology and consequently their stock could be jeopardised such costly experiments could be avoided.

As most species resident in the Tungabhadra reservoir breed in the river above and do not try to migrate downwards or their stocks in the river stretch above or below are threatened, no device for facilitating migration of adults or young is necessary.

As sluice take offs are some 50 to 90 feet below the maximum reservoir level and at the far end of the 16-20 km diameter deep reservoir zone, it is unlikely that any 'local' or short distance migratory fish seek these openings and are lost. Moreover, none of the young fish of the major species known, reach these depths in search of food. Their eggs, larvae or fry may not drift to this region on reaching the reservoir from the river some 80-85 km above. They seek inundable shallow margins in upper waters of the reservoir as established.

The tail race emptying into the river partially attracts considerable numbers of fishes from the river below especially those seeking breeding grounds during monsoon. When large amounts of water are let out in the river and while spill gates are opened, there is an accumulation of fish in pools below the dam for 2-3 kms. Puntius kolus, P.dobsoni, P.pulchellus, Labeo fimbriatus, Labeo calbasu, L.potail, L.porcellus etc., are subjected to such large scale destruction. This may well affect the stocks below. As in Mettur, there are no concentrationsof major carp fingerlings for implementing rescue operations and planting in the reservoir. Regularly conducted sampling programme for three years shows that except for minor or medium fish fingerlings (Labeo porcellus, L.potail, L.bata, Cirrhina reba etc.) no major species except stray Tor sp. and L.fimbriatus are available below. On the other hand, considerable numbers of catfishes, Mystus. maydelli, Bagarius bagarius, Mystus aor or M.seenghala are found below, along with Schizmotorhynchus nukta or Garra spp., which are rapid water rocky forms. It is interesting Pseudeutropius taakree, Silonia childrenii and Osteobrama vigorsii are seldom recorded in the river below the Dam. O.vigorsii is replaced by O.neilli both above and below the reservoir in the river stretches. It is likely that the river stretch below the Dam and especially after diversion of water into the river 14-16 miles below, through escapements, has improved in fisheries value as deeper and wider areas of water have come into existence.

After the Tungabhadra reservoir has been filed, fish catches have improved in the river above. Larger sized / to have been (higher age groups) endemic species- Labeo fimbriatus, Puntius dobsonii, L.potail as well as Silonia childrenii, Pseudeutropius taakree etc., are reported/caught consistently. Of the cultivated forms, Catla catla ranging in weight from 15 to 20 kg frequently occur as far as Shimoga. Between 1940-46, there has been no record of any Catla in the stretch. Since the last 4-5 years, stray Labeo rohita and Cirrhina mrigala are caught. As there is no stocking of rivers above by these species these forms undoubtedly are escapes from the Tungabhadra reservoir.

Canals :

Problem of developing thousands of miles of irrigational and power canals and distributories from Dams, weirs and barrages for fish raising and manipulation of stocks as ancillary to food production programme, has not been given its due, except in the Arrah canal from the Sone barrage and the proposed Gandak Project, both in Bihar. Tungabhadra reservoir has following canal features:

	Right Bank		Left Bank
	Low level canal	High level canal.	Low level canal
Sluice take off level	1550 ft msl	1610 ft msl	1560 ft msl
Length	217 miles	122 miles	141 miles
Width (Bed)	72 ft.	65 ft.	84 ft.
Discharge	2500 cusecs	4000 cusecs	7000 cusecs
Depth	1015 ft.	12.0 ft.	14.0 ft.
Velocity	3.0 ft/sec.	4.5 ft./sec.	6
Escapes	10	5	106
No. of Main distributories	56	-	468 miles
Length of Main distributories	127	-	

- The Roya and Basavanna canals of 17½ and about 10 miles each, being original canals are now supplied water through dam sluices. Their capacity is 216 and 139 cusecs respectively.

All canals and distributories are 500 and 1000 miles in length respectively. The right bank low level canal for 14 miles is known as power canal. Of the water drawn into it (2500 cusecs) 700 cusecs, are released into the river with 1800 cusecs left for canal irrigation. Similarly the left Bank canal has a capacity of 7000 cusecs of which only about 3100 cusecs is being drawn. The high level canal functions from July 1966 for about 6-7 months a year, and will stop drawing water when reservoir level reaches about 1610 ft msl.

Table 31

Percentage composition by weights and total length range of species in three and five distinct parts of right bank canal in 1965-66 respectively.

Species	% in 1965 by weight			% in 1966 by weight					Length range in mm.
	I	II	III	I	II	III	IV	V	
CARPS:									
*P.kolus	2.98	6.49	-	32.6	20.2	81.5	40.1	1.4	210-325
*P.dobsoni	7.98	8.32	-	-	0.2	-	11.0	5.0	153-450
P.pulchellus	0.37	-	-	-	-	-	-	-	345
*P.sarana	0.07	12.50	-	-	0.5	2.8	-	4.5	102-231
P.stigma	-	0.02	-	-	-	-	-	-	87
*Tor spp.	6.28	1.04	20.52	4.1	36.5	-	4.2	1.4	116-896
*L.fimbri-[illegible] atus	33.31	11.86	23.17	10.6	14.0	-	9.2	11.9	257-745
L.porcellus	-	0.66	-	-	-	-	-	-	175-215
*L.potail	0.93	28.91	-	-	-	-	-	-	167-325
*L.calbasu	4.96	-	2.77	0.8	0.2	-	-	10.5	200-900
*L.bata	0.55	-	-	-	0.2	3.2	10.5	1.2	112-355
L.rohita	-	-	-	-	-	-	0.2	-	250
*L.pangusia	-	-	14.98	-	-	-	-	-	500-635
C.reba	0.15	0.90	-	-	0.1	0.1	0.1	0.5	205-255
C.mrigala	-	0.74	1.94	-	0.4	-	-	6.4	260-440
*S.nucta	0.42	1.07	-	0.2	0.2	0.3	0.2	-	121-320
*S.thomassi	0.59	6.19	-	-	-	-	-	0.2	195-265
*O.vigorsii	-	0.05	-	-	0.3	-	-	0.2	140-234
O.neilli	-	0.15	-	-	-	-	-	-	122-132
O.ogilbi	-	-	0.02	-	-	-	-	-	72-116

Contd..Table 31

	I	II	III	I	II	III I	IV	V	
CATFISHES :-									
M.punctatus	13.55	2.08	-	-	-	-	1.5	-	255-635
M.aor	1.94	16.23	-	1.2	1.5	-	-	-	380-765
*M.seenghala	-	-	-	0.9	17.3	-	-	32.3	390-1100
M.cavasius	-	0.45	-	-	-	-	-	-	140-183
*B.bagarius	25.92	0.24	32.74	49.6	5.0	-	23.0	13.0	290-1040
W.attu	-	-	3.88	-	-	-	-	-	745-955
*O.bimculatus	-	0.50	-	-	3.0	-	-	4.5	175-280
O.pabo	-	0.19	-	-	-	-	-	-	261
R.pavimentata	-	0.28	-	-	-	-	-	2.5	160-210
R.hastata	-	0.24	-	-	-	-	-	0.1	95-155
P.taakree	-	0.24	-	-	-	-	-	-	145-263
N.notopterus	-	-	-	-	0.4	-	-	2.9	208-230
MISCELLABEOUS :									
Oxygaster spp.	-	-	-	-	-	2.1	-	-	125-140
Garra spp.	-	0.06	-	-	-	-	-	-	171
R.daniconius	-	-	-	-	-	-	-	-	7[illegible]
N.khavalchor	-	0.40	-	-	-	-	-	0.2	200-208
G.giuris	-	1.17	-	-	-	-	-	-	230-235
C.marulius	-	-	-	-	-	-	-	1.1	396

* These forms also either dominate by numbers or occur very frequently in canal catches.

The escapements from the low level canals drain surplus water into the river through channels. The surplus water through the sluices and turbines is also let off into the main river close to the dam on each bank through surplus channels almost throughout the year, thus opening a high way for any fishes to enter the canals from the river.

The canals are lined in their major lengths with cement masonry. There are also some widened bays especially within older tank beds within the canal lengths. There is one forebay of 80 acres 14 miles below on the right bank power canal which later becomes the irrigational canal after passing through the turbines.

During summer, between April-May when canals are shut for 20 to 25 days the fish catches in them have varied from 50 to 154 kg per each section of 4 to 6 miles (table 31). Larger sized specimens are available in the upper stretch of the canals rather than in the lower stretch. No data for the entire length are available.

From the data on fish captured in the canals, species composition is found different from that of the reservoir. A high percentage in weight is provided by such rare forms like Bagarius bagarius, Mystus maydelli, Rita hastata, Osteochilus thomassi, Schizmatorhynchus nukta, Labeo pangusia, Labeo bata (L.boga ?) all of which are torrential rapid water forms found in the river below the Dam. The small Nemachius and Lepidocephalus, and even Garra or Tor spp., are common. It is interesting that stagnant water minnows viz. Puntius stigma, P.chola, P.ticto, Rasbora, Esomus, Aspidoparia most Osteobrama spp. etc., are rarely represented. Even Oxygaster spp is poor. All this indicates that only larger and hardier fish that can withstand high currents and negotiate rapids are found in these canals.

With poor plankton, benthic biota and macrophytic vegetative cover available, the fish species noted are either predaceous forms or those that can scrape the canal linings for sessile and filamentous algae. Patches of Vallisneria are found edging margins of the canals. Hence only those species that live in water currents or rapids subsist on available food and also those that can recruit from the river are common.

Recommended Measures :

1. Majority of mature larger species of fish escape from the reservoir into the main river simultaneous with incursion of flood waters from end of May. At this time reservoir's topwaters will be near Muthukur and the lotic stretch up to Mudalighatti and for 30-40 km above, should be prohibited from being fished for about a month. While catfishes can be permitted to be removed, at least carps (stocked varieties) have to be guarded.

ii. A comprehensive survey of river above reservoir should be conducted charting pools, breeding grounds, fishing villages, fish concentrations, young fish etc.

iii. For 5-8 km fishing should be prohibited below the dam and extensive poaching taking place stopped.

iv. The river below has to be licensed for fishing by the Department of Fisheries as colonies of fishermen have taken advantage of improved fishing conditions after the construction of the Dam.

v. The canals totaling in all 1500 miles are potential source of fish production; due to uniformly deep and high velocity currents fish species are restricted as without stagnant pools and vegetation, plankton and other fish food organisms are highly restricted in density. The escapements connecting river below at various points and also at the Dam site should be so regulated as to attract river forms into the canals. As the majority of fish in the cement masonary lined lengths are torrential river species (Bagarius, Schizmatorhynchus, Rita, Tor, Labeo fimbriatus, L. calbasu, Osteochilus etc.), this ecological set up should be followed up, stocking, if possible, by these forms.

It is not advisable to stock the masonry lined canal lengths with Gangetic carps or Cyprinus carpio, which can be stocked only in unlined, earthen canals or distributories much lower down, where nutritional elements are higher.

vi. The Hampi forebay and other similar expanded areas of canals can be stocked with Mahseer fingerlings. These can be grown in the Tungabhadra fish farm and propagated as the forebay may become rich with the species for angling by tourists.

vii. The canal escapements should be so operated to coincide with fishery conditions. When large concentration of any river fish are found below the dam, they can be diverted through the escapement channels into the main canals by regulating the flow. This will automatically enrich the canals.

RECRUITMENT, STOCKING AND ACCLIMATISATION

Recruitment:

Even though indigenous carps and an abnormally high survival of catfishes now sustain self generating stocks of fish from year to year in the reservoir quality species are lacking. A ∠and wild ∠ coarse fish population recruiting itself from the main river is not comparable in value to three Gagetic carps in rate of growth and sizes. The catfishes as shown, feed upon young carps and minnows that actually subsist on the lowest food chains. Hence, detritus, plankton and other decaying matters are being utilised by existing fish population only indirectly. Conditions for recruitment and survival of carp fry though possible to a greater extent due to the wide ∠ inundated upper ∠and marginal areas, overwhelming number of catfishes destroy the carps. This structure has to be changed by removal of catfishes to encourage survival of major carps. At present local species though recruited during the breeding season, ∠not can ∠ be expected to survive and form the main fishery of the reservoir.

Stocking :

Stocking with quality fish to observe stocking success and to implement measures to enable them to naturalise by facilitating their breeding in the reservoir or its vicinity is the primary object of fish farms attached to reservoirs. In the Tungabhadra reservoir survival of stocked fish appears very poor as most of this stocking is done, not where food and shelter is expected to be available for the farm grown fish, but in the deep "aquatic desert" area of Zone IV where no food is available. Fish are here left to fend for themselves under adverse ecological conditions. If adequate numbers of early to late fingerlings are introduced in September-December within inundated bays and inlets, they would grow quicker and probably remain within the reservoir. Stocking as is being done in March-April should be abandoned.

Inadequacy of earlier stocking procedures is reflected only in stray occurrences of the forms. Because these stray forms may be widely distributed, chances for the opposite sexed fish to come together in the long stretch of rivers above during spawning season are remote. Even considering escapements, if adequate numbers had been introduced they would probably have bred similar to endemic carps above.

The major aspect of development of reservoir, e.g. stocking with suitable species of fishes and prawns and pursuing the trend, has not been taken up adequately in the Tungabhadra reservoir as in other reservoirs where such measures are given priority.

Recommended Measures:

i. Intensified capture of all species of catfishes, Osteobrama vigorsii etc., within the reservoir and river stretches above to bring down unwanted fish population. Shore seines should be encouraged all round the year with the strictest understanding that any "stocked" fish caught should be released. Gill nets and, hook and line fishing can also be encouraged for removal of exsisting undesirable species.

ii. Stocking programmes should be taken up on a far larger and wider scale, increasing numbers and species of varieties. Cirrhina cirrhosa, Pangasius pangasius and prawns could be tried. Suitability of the environment for prawns is reflected from the avilable small Leander spp., in Tambrahalli and other topwater areas in littoral zone. Macrobrachium will probably thrive even better.

iii. Survival rates of stocked fish to be followed up by experimentally holding them in cement cisterns and perfecting the tagging techniques. Meanwhile fin clipping and other easier means of assessing stocking success should be devised.

iv. Possibilities of impounding shallow areas along the reservoir margins in inundated inlets as seminatural nurseries for great numbers of fry from the fish farm, can be explored. This will release nursery space of the fish farm and at the same time chances for greater survival and final breeding of quality species will be very high.

EXPLOITATIONAL AND DEVELOPMENTAL MEASURES

Unlike most reservoirs where exploitation of fish stocks is difficult, Tungabhadra reservoir is situated very favourably for commercial exploitation by known and easy methods of fishing. The reservoir is highly exploited by surface gill nets and shore seines as already described. Hence devising new or better fishing methods is superfluous.

Present methods of fishing employed appear adequate in the existing levels of fish composition, though returns may not be commensurate with the effort in gill nets. More gill nets and shore seines will increase production and it is advisable to do so in the context of high catfish concentration. It is too early by investigations so far undertaken to mention if depletion trends are noticeable. Even in the last two or three years there is a perceptible change in composition, and several species indicate decreased sizes. Under the circumstances, the following measures may be necessary.

i. Popularising bottom set gill nets and persuade fishermen to use them more extensively, as the bottom nets are now computed to capture 60.4% more number of fish and 70.2% more weight than surface nets. Fishermen are reluctant to operate bottom nets due to increased labour and fear of damage to nets. These can be countenanced easily.

ii. The "hobbled" gill net successful in T.V.A reservoirs may be tried. This presents features of a "trammal" net; single meshes in one single net being hung in infinite number of hanging ratios, are adopted to capture variously shaped fishes with several size ranges both gilling and enmeshing them.

iii. Shore seines can be longer and may be aided by outboard engine during operations.

iv. There is little need for a programme of cutting submerged trees to aid fishing of any kind as area available for fishing even otherwise is vast.

v. Fish finders (Echo-sounders) to be operated to locate any shoals or concentrations of fishes. It is surmised that _Silonia childrenii_ and _Mystus cavasius_ shoal in the reservoir as observed by nature of their occurrence.

vi. In the present context of high output (though low economical rates) fishing devices such as electric stocking methods, light fishing etc. are unnecessary. But by varying voltages, light intensities, colour and so on it is probable that selected varieties alone may be fished. These can be tried to destory the present superabundant catfishes.

vii. Devices that can be tried easily by local villagers such as traps and bush shelters for attracting fishes may be popularised.

viii. Boats for all purposes should be employed as coracles endanger lives of fishermen.

The following developmental, exploitational and research methods on reservoirs in India are envisaged with the background knowledge acquired at Tungabhadra Dam.

i. A survey of reservoirs in India categorising them on the basis of main stream, diversion and closed reservoirs with concomitant fish fauna and essential limnological samplings. It is computed that there are 295 reservoirs with a total water spread (maximum) of 11,96,000 ha in India.

ii. Close Co-operation and Co-ordination of research and developmental programmes by Central and Departmental units.

iii. Fish farms to be set up on the lines of Tungabhadra Boards' Fish Farm at all major reservoirs, and a proper programme for meeting the stocking requirements of a reservoir adhered to conjointly. Species of fish, sizes, timings of stocking, marking and recovery programmes to be coordinated.

iv. Surveys as to fishing operations commercially feasible on each reservoir to be correctly made depending upon nature of bottom, shore line etc., Greater attention towards fishermen, collection of fish, disposal also to be given. Correct data on fish species and landings should be maintained.

v. Most reservoirs are likely to be amenable to gill net and shore seine operations, Extension of bottom nets and 'alivi' in such reservoirs with the knowledge gained by conditions in the Tungabhadra reservoir, to be implemented.

vi. It is inadvisable to keep a Central Unit tied down to one single reservoir for years. A centrelly situated Lacustrine Unit, with a Chief Biologist, a Chemist, Statistician, Bacteriologist, Planktologist, Invertebrate Zoologist (For Benthic and Littoral Fauna) two or three Fishery workers studying fish biology, food, growth, reproduction etc. as the case may be in a comprehensive manner, can coordinate basic observations on a number of reservoirs simultaneously.

viii. Several aspects of research that were not undertaken in the present studies - e.g. bacterial and fungal work, epiphytic ooze and 'tripton' samples for determining fish food production capacity of bottom detritus can be undertaken. Present plankton and other biotal samples are unsatisfactory. Vertical and horizontal hauls of plankton, amount of water seived etc have to be used and improved presentations are necessary. Similarly, bottom and littoral fish pond production has to be undertaken correctly under synoptic surveys and production per/ha. in a wet and dry weight expressed statistically.

viii. One of the problems faced by storage reservoirs is threat of population of the storage water by industrial plants being erected along the margins. Steps have to be taken to prevent pollution hazards to reservoir waters before industries are set up and to avoid fish loss as in the Panchet reservoir by Sindri Fertilizers Factory.

RECOMMENDATIONS, FUTURE SCOPE FOR WORK AND SUMMARY

RECOMMENDATIONS:

I. Basic Fertility:

The Tungabhadra reservoir in common with all other reservoirs of India is subjected to changes determined by the yearly monsoon. Tropical weather conditions e.g. sunshine and temperature, are highly conducive to bacterial activity and energy storage by photosynthesis.

Favourable morphometric and edaphic factors further influence fertility levels, as the reservoir is shallow the area under ten feet depth being 18.3 to 30.6 percent of the total area.

Nutrients in the soft deposited silt and alluvium (upto 17 percent organic matter) are high due to their rich allochthonous nature, and are subjected to considerable bacterial activity with increasing temperatures and decreasing water levels. They are leached into the water medium by the prevailing wind and wave actions enriching the water constantly.

Water in this mainstream reservoir is constantly being flushed being drawn off at the bottom (50 to 80 feet below the surface). By exchange of water there should be no build up of fertility as in deep ravine reservoirs. But in the Tungabhadra reservoir, there is no difference between the surface and bottom layers of water and a high degree of oligotrophic condition is present almost round the year. Water let down below the dam shows chemical conditions similar to the main reservoir surface water.

(1) Studies on basic productivity are to be continued four times a year once in each season, in all the zones for assessing the fertility trends on year to year basis.

(2) Cultivated marginal lands are adding to the fertility levels of the reservoir on submersion. Excessive cultivation can induce earlier siltation of the reservoir while adding to vegetation cover in the

bays and creeks, which may have to be discouraged beyond a certain limit.

II. Fish food: Littoral, Bottom, Plankton i.e Organisms and Forage Fishes:

Water level percentage upto 10 feet remains almost constant presenting always a rather biologically rich area which maintains invertebrate food organisms in sufficiently high intensity. Benthic organism, e.g. aquatic insects including chironomids and molluscs, increase in numbers in zones III and IV with the slow draw-down of 7 to 10 cm per day. Desiccation and disintegration of aquatic flora occurs once the reservoir level starts lowering in January. Higher marginal temperatures and wave action from April to June further kill molluscs whose dead shells litter the bottom. They tend to add to the calcium carbonate components in soil deposits which are available to the overlying water as bound carbondioxide enriching the plankton.

Plankton appears to be quite adequate and is richer than either in Bhavanisagar or Mettur reservoirs. With disintegration of marginal deposits, rich carpets of sessile microvegetation e.g. diatoms and chlorophyceae is observed. These (Difflugia, Arcella, Ceratium, Keratella, Brachinus, Navicula, Synedra etc.), are dislodged and add to the plankton constituents.

The reservoir holds a young juvenile or maturing population of catfishes, which require an abundance of forage fishes as food. Several minnow carps, Osteobrama, Notopterus and the small freshwater prawn-Leander spp. are found in catfish guts in quantity. Further, minnows dominating during high water levels (-September-December), are reduced in abundance by April-May, being obviously preyed upon by catfishes, which then switch over to insects as on alternate food in Zone III. The prey population remains high during the catfish growing season. Cirrhina reba, Oxygaster spp. Aspidoparia, and several small Puntius spp., feed upon detritus and plankton. Factors such as sudden draw downs or failure to reproduce by the forage forms are features not known to be present in the reservoir. Absence of stunted catfishes indicates also sufficiency of their food.

(3). Average standing stocks of invertebrates should be assessed and indices of their productivity computed. (1.17 cc of invertebrates per sq. foot in 3.5 acre area are known to produce about 866 lbs of fish).

(4). Predator-prey ratio and relationship amongst the population are to be established year to year (if not season to season) by the study of abundance, composition, sizes and food of various species that are involved or interrelated.

(5). Reproductive phases and relative abundance of molluscs, insects and forage fishes and of the prawn Leander spp. are to be ascertained and related to water levels as they are influenced greatly by fluctuations in water level.

(6). Standing stock of plankton by sieving 50 or 100 litres of water in each zone may be computed by volume and weight on monthly basis.

III. Fish Production: Statistical Assessment and Exploitation.

Considering the production figure of 235 metric tonnes during 1965, hardly 6.2 kg/ha of fish are computed for the maximum surface area of about 37,000 ha. This refers to fish harvested and not the 'standing stock'. From the 'alivi', a standing crop of 13.4 kg/ha was computed almost continuously over a period of four to five months in zones II and III. But had catch composition consisted mainly of fast growing Gangetic carps feeding upon lower food chains (like detritus, plankton, aquatic weeds, molluscs and insects) instead of the present slow growing or medium carps and a super abundance of catfishes, production could have been perhaps much higher.

The value of fish landed is of the order of Rs.1,17,500 during 1965 at the rate of 0.50P per kg. Fishermen were deprived of their rightful earnings by the 15 or so fish traders who appear to profit each by Rs.18,000-20,000 each year. Otherwise, the reservoir even now can yield some Rs.3 to 4 lakhs by sale of fish if middlemen are excluded i.e. a Fishermen's Cooperative Society handles the commercial fishery. Each labouring fisherman earned Rs.30-40 per month for eight months though he should have got Rs.90 p.m. his major earnings having been diverted to fish merchants. Alivi catches though producing Rs. 1000-1500 per month / unit, the owners were paid only Rs.400-650 by merchants who undervalued the catches and made adjustments towards advances and other accounts. Gill net fishermen fared slightly better asthey own nets and usually obtain bigger fishes.

There is at present no way to collect correctly the data on fish landings, especially during the main fishing season (January to June) as the major catch is disposed off at centres on the left periphery which are not easily accessible. The problem becomes still more acute between March and June with the water level going down further.

The reservoir can be exploited all over by gill nets but alivi operations, except in Zone IV, are easy as there are few tree stumps or similar obstructions. Except for two to three months in a year (Mid-June to September) fishing is relatively easy. Even during the monsoon season, considerable quantities of Puntius sarana and minnow carps are caught at some centres.

The reservoir is thus potentially quite productive in fish and catchability of stock far higher than in other similar reservoirs. From what has been studied, there is no decline in yield per fishing effort and no downward trend in total production in the face of increasing fishing pressure.

(7) An agency for recording actual total production, species and size composition of fish from all centres should be established. A well organised Fishermen Cooperative Society with one or two major launches, can help in such assessment. Catches of fishermen based on gear, should be continued to be statistically recorded for computation of total yield equated with fishing effort. Catch per unit of effort should be studied and fishing gear standardized.

(8) Benefits to fishermen have not been as much as they should have been as they were left to fend for themselves after licences were issued to them. Ice

should be supplied to the fishermen of the fishing spots for the preservation of their catches for final assembling at the cold storage plant at Tungabhadra Dam. This will also control their activity and solicit their help for adoption of any conservation measures such as closed seasons, species size, gear restriction etc. designed towards ensuring a better fish yield in later years.

(9). The Reservoir can be exploited on a much larger scale by the existing fishing methods. This will also serve to eliminate the dominant catfish population.

(10). Popularising bottom gill net operations (during experiments 60.4 percent more by numbers and 70.2 percent more by weight of fish were obtained) will increase the catches as well as help to eliminate the larger predaceous forms. Bottom gill net - 'uduvala' should also be encouraged especially in Zone IV.

IV. Species Composition and Improvement of Stocks of Fish :

Of the 81 fish species recorded in the reservoir, 35 are commercial forms. Though 19 are carp species, bulk of the catches in 1965 and 1966 were formed by 12 catfishes to an extent of 80.2 and 75.8 percent as against 16.1 and 20.2 percent of carps respectively. These percentages refer to the rather nonselective alivi catches and indicate fish composition of the area unlike in gill nets that are highly selective. Pseudeutropius taakree amongst catfishes and Puntius kolus amongst carps predominated the catches and constituted 23.1 and 3.9 percentage respectively. Both the species are comparatively small and are not popular outside the region. Additionally there are numerous minnow carps and a rich forage fish population. The carps consist of adult and young Cirrhina reba, Puntius sarana, P.kolus, Labeo fimbriatus L. potail, L. porcellus with stray Puntius pulchellus and P.dobsonii. While very young catfishes are scarce, juvenile and immature stages form the bulk of the catches being considered 'coarse' rather than prime varieties. Besides, Osteobrama vigorsii is also found in bulk in the reservoir. Hence, fish composition shows mainly medium sized fishes unsuitable for large scale commercial production.

Stocking a reservoir with selected fish fingerlings (Gangetic major carps) is the primary objective of the attached fish farm. In the Tungabhadra reservoir, stocking appears to have been inadequate and survival poor, since such stocking was mainly restricted to Zone IV where nursery raised fingerlings do not immediately get adequate shelter and food.

(11). Stocking with major Gangetic carp fingerlings should be done before December in Zones II and III. If a larger number of fish fry are produced in the farm in July-August, than what the farm can handle, they can as well be stocked directly in the above zones with a high chance of survival as the ecological conditions of shallow bays are very favourable at the time. This will save nursery space and any large scale mortality of fingerlings when handled. Utilisation of shallow margins during high level conditions as semi-natural nurseries by impounding even certain areas and releasing the fingerlings later, is a possibility to be explored in the reservoir.

(12). Besides the major Gangetic carps, stocking with Cirrhina cirrhosa and Silver carp (Hypopthalmichthys molitrix) can also be considered. The reservoir is not suitable for receiving the sluggish Common carp Cyprinus carpio as predaceous fishes are apt to eliminate the species. Pangasius pangasius fingerlings can be directly stocked as this catfish is not predaceous, feeding mainly on molluscs which are abundant in the reservoir, and at present are not utilised by any other fish as a major item of food.

(13). The freshwater prawn Macrobrachium malcolmsonii may also be stocked as the environment appears to be very suitable for prawns if the present availability of Leander spp. is any indication.

V. Fishery Biology and Dynamics of Fish Population:

(14). Fishery Biological studies on commercial species, if continued further in correlation with changing ecological condition of the reservoir with the passage of time will serve to form the basis for formulation of fishery management practices in a dynamic manner. Study of population dynamics will help to regulate fishing on the basis of eumetric curve.

VI. Fish Escapement, Migration and Recruitment:

The surival of fish species available in the reservoir is threatened by its inability to descend or ascend the dam for completion of its life cycle. But the tail races attract fishes from the river stretch below, which are poached for 2-3 km in large numbers during surplus discharges. *Puntius kolus*, *P.dobsonii*, *Labeo fimbriatus*, *L.calbasu*, *L. potail*, *L.porcellus* and catfishes like *Wallago attu* and *Mystus maydelli* were recorded in such catches.

There is a constant threat of fishes from the main reservoir escaping into the river above unlike in the smaller reservoirs fed only by seasonal rivers and streams. By escapement from the reservoir, large sized endemic species as well as stocked Gangetic forms, are regularly encountered in the catches in the Tungabhadra as well as in the Tunga and the Bhadra rivers above. The rivers thus appear to have been somewhat enriched by the stocking programme already carried out. During trial fishing observations, stray *Catla catla*, *Labeo rohita* and *Cirrhina mirgala* were recorded as far above as Shimoga, Honnali and Harihar. Sixty percent of these carps by weight, are reported to consist of *Catla* each weighing upto 15-20 kg. The regulated but higher volumes of water below the Tunga barrage and the Bhadra Dam, have created deeper pools sheltering stray escapees from the Tungabhadra reservoir. It was also found that larger sized endemic species were being captured in the rivers since these barrages and dams were constructed.

Recruitment of endemic carps into the reservoir appears to be considerable as large quantities of *Labeo porcellus*, *L. potail*, *L. fimbriatus* and a few *Puntius dobsonii*, *P.pulchellus* eggs and larvae are brought in during monsoon floods. They are also recorded to survive in the sprawling shallow bays in Zones II and III but while growing they are destroyed by the dominant predaceous fishes and may even escape into the river above. There was no evidence until 1966 that Gangetic carps had at any time bred above the reservoir as no larvae, fry or fingerlings were recorded.

(15) Migration of carps into the river, whether endemic or stocked, cannot be prevented from the Tungabhadra reservoir especially during monsoon floods. But their large scale capture in the topwaters (Zone I and river stretch for 8-12 km) by gill nets set across the channels should be totally banned from about the middle of May till end of July when such migrations occur. Similarly, protection of quality species confined in Zone IV during summer dead storage levels should be provided and restrictions on number of units operating, species and sizes, imposed to prevent their destruction on a large scale.

(16) Migrating catfishes, however, may be allowed to be captured, and selective fishing developed and enforced to minimise their breeding and recruitment into the reservoir.

(17) Release of all immature Gangetic carps if captured in the reservoir and in the river above, should be imposed for some years.

(18) A comprehensive survey of the rivers above the reservoir should be undertaken and records of major carps caught at various centres, should be maintained by the Department of fisheries.

(19) There should be a complete prohibition on fishing for 5 km below the dam, to prevent denundation of natural river stock by destruction of breeders irrespective of species.

(20) Spawn recruitment explored as in years 1963-1966, should be continued at Shingatalur, Mudalighatti and Hesarur centres (Zones I and II).

(21) Young fish studies designed to find the surviving

species as well as to estimate recruitment should be continued as they immediately provide a clue to the success and self recruitment, if any, of stocked species.

VII. Canal Fisheries Development

Tungabhadra canals and their main distributories are over 1500 miles in length, there being two main low level canals of 217 and 141 miles in length and a high level one 122 miles long. The capacities of the canals are 2,500, 7,000 and 4,000 cusecs respectively. A special feature of the two low level canals is that surplus water can drain through channels close to the dam into the river below connecting the tail races, creating passages for fishes to enter the canals from the river. There are also 21 escapements from the three canals which drain surplus water through channels into the river below, many of which also enable some strong swimmers to enter these canals. These passages and escapements when open serve to enrich the two power-cum-irrigational canals.

The main canals however are lined with cement masonry to reduce maintenance cost, prevent percolation and weed infestation. There are also several wide bays and one forebay (30 ha), 14 miles below the right low level canal close to the Hampi power house.

During investigations, when parts of the canals (30-50 km below the dam) were shut down for annual repairs, the fish catches were found to vary from 50 to 154 kg per stretch of about 8 km, and in parts 10 to 31 kg per mile length not inclusive of unauthorised capture elsewhere when levels were already low. The species composition by weight and percentage of fishes as sampled 3 and 5 times in 1965 and 1966 are presented in table-31.

A high percentage composition of rare reservoir species like Bagarius bagarius, Mystus maydelli, Rita hastatus, Osteochilus thomassi, Schizmatorhynchus nukta, Labeo pangusia and L.boga is observed in the catches taken in canals. All these are rapid water riverine forms that could have ascended the canals only from the river. The smaller rocky and sandy forms like Lepidocephalus spp., Nemachilus spp. and Garra spp. were also noted unlike in the reservoir, along with juvenile Tor spp., Puntius stigma, P.chola, P.ticto; Oxygaster, Rasbora, Esomus and Osteobrama spp. were seldom represented. Composition and size ranges indicate that only some well grown fishes that can withstand fast currents and are able to negotiate high velocity discharges in the passages between the river and canals are found in the canals.

Plankton, benthic biota and macrophytic vegetation were found to be poor in the canals. Patches of Vallisneria were occasionally found edging the canals. The fish species recorded are either predaceous or such that can scrape the canal linings for sessile filamentous algae.

(22) The canal surplus channels close to the dam may be operated, if possible, to coincide with large concentrations of river fish when they can stock themselves in the first few miles. It is futile to stock the upper stretches with fingerlings of quality fish.

(23) The lower or mud-lined subsidiary canals alone can be stocked with suitable varieties of fishes as the water is expected to be rich. Stress may be given to stock mainly endemic carps rather than Gangetic carps which necessarily have to be removed within 8-10 months after stocking.

(24) A record of present fish catches in the main canals and subsidiaries should be maintained.

FUTURE SCOPE FOR WORK :

(1) Study of particulate and disintegrating matter, nutrients deposited in the ooze, extent of bacterial and fungi activity, may be made.

(2) Computation of relationship between production of aquatic invertebrates (standing stock) and total production of fish may be made and index of such productivity for the reservoir defined year to year.

(3) Along with plankton, 'tripton' - i.e. nonliving particulate matter as well as epiphyton (periphyton) have to be studied as both deposited particulate organic matter (in ooze) and epiphyton form considerable part of food for bottom feeders as well as young stages and smaller species of fishes.

(4) Suitably designed 'trap' nets in Zones III and IV may be tried as they will eliminate shifting of fishing activity between January and June from one place to the other. Experiments for capture of fish by "hoop" nets can also be conducted as many bottom fishes are expected to be captured.

(5) Alivi nets may be operated with the help of power boats for encircling fish concentrations quickly and to save labour and time.

(6) Fin clipping and tagging programmes may be initiated for study of fish population dynamics. To begin with fin clipping can be tried on fishes that are being stocked as also selected endemic fishes.

(7) Investigations are required on planting trends of river fishes in the canals through the escapements. Some conservational and operating measures have to be thought of to enrich the canals by river fishes.

(8) The Hampi Forebay and other similar extensive areas in the canal lengths can be stocked with predaceous Mahseers to attract anglers. Such bays are not rich enough for major carp stocking.

(9) New industries around the reservoir can be started only if fish life in the reservoir can be maintained safely. Otherwise fish losses due to pollution in the reservoir as in Panchet reservoir (D.V.C.) will always pose a threat to the fishery development programme.

SUMMARY :

(1) The multipurpose Tungabhadra reservoir in Mysore State has a waterspread of 37,814 ha (146 sq. miles) at maximum water level, is 80 km long with a maximum depth of 41 m and a mean depth of 9.8 m. Shoreline is 337 km at full and 85 km at dead storage levels. The reservoir was divided into four zones e.g. Zone I-Riverine, Zone II- Transition, Zone III- Shallow and Zone IV- Deep, for a study of its limnology, fish production and composition, experimental exploitation and fish biological studies. These studies mainly relate to the regular fortnightly and monthly observations taken between October, 1963 to September 1965 and also include some data collected before and after this period.

(2) The soil features of the reservoir indicate that the original characteristics are replaced by deposited silt mainly in Zone II. Soil, however, is rich in calcium (4000-6000 lbs/acre), and magnesium (500-2000 lbs/acre) with pH-8.0-8.5, specific conductivity 82-261 x 10^{6} mhos. and average organic matter 17 percent in Zone III, which covers 22.8 percent of the reservoir. Other zones indicate lower values.

(3) Water conditions indicated a temperature range of 23.1 to 29.5 turbidity upto 825 ppm and pH range of 7.9 to 8.5. Dissolved oxygen was 6.4 to 11.1 ppm (surface and bottom). Primary productivity experiments indicated low values in general, and shallow zone (Zone III) was rich with values of 5.3-10.4 mg C/M^3/day as against the deep part (Zone IV) which indicated 3.38-5.72 mg C/M^3/day. Alkalinity was 31 to 114 ppm due entirely to carbonates and bicarbonates. Specific conductivity was highest (225-662 x 10^{6} mhos) in Zone III and lowest (125-213 x 10^{6} mhos) in Zone I. High concentrations of chloride (11.9-42.1 ppm), nitrate (0.11-1.52 ppm), silicate (6.9-20.5) and iron (0.12-1.32 ppm) were recorded. Though in traces generally, as high as 3.3 ppm of phosphate values were also recorded.

(4) Macrophytic vegetation comprised at least 17 genera, that were subjected to great seasonal variations according to water levels. Zone III was richest with 12 genera and Zone IV rather poor with only 4 genera. Cyperus exaltatus was common all over the reservoir Aponogeton, Marsilia etc. were confined to margins; Potomogeton, Nais and Ceretophyllum were recorded in marginal lagoons. No large scale colonisation of rooted or floating vegetation is discernible in the reservoir.

5) The littoral and benthic fauna were related mainly to soil and presence or absence of water currents. Zone III was rich in molluscs in general (293-340 units/sqm). Zone IV showed upto 516-557 units/sqm consisting mainly of gastropods as they tended to concentrate on the margins due to wave action. Zone I indicated predominantly insects (195-337 units/sqm); bivalves preferred also the fluviatile conditions of Zone I. Chironomids were maximum in Zone III and oligochaetes in Zone II.

(6) Zone I and II were dominated by phytoplankton in the

first year, ratio between zoo and phytoplankton being 1:7 and 1:12 with zooplankton peaks at 11 and 17 units/l as against phytoplankton peaks at 68 and 188 units/l respectively. Phytoplankton dominated in the second year also in these zones. Zone IV showed a predominance of zooplankton over phytoplankton (3.5 : 1.0), zooplankton peaks being at 32, 560 and 24 units and 63, 68 and 17 units/litre during the successive years. However, plankton production was the highest in Zone III being dominated by zooplankton in the first and phytoplankton in the second years, both copepods and protozoans occurring successively. Phytoplankton production period followed the south east monsoon flooding, the dominating groups being Diatomaceae, Chlorophyceae and Myxophyceae in that order. Appreciable quantity of sessile and epiphytic organisms from Zones II and III enriched the water plankton by continual dislodgement from the margins.

(7) Biological studies on food, maturity, spawning and growth of 13 commercial species of fishes were conducted. Puntius kolus showed a preponderance of vascular plants, insects and small molluscs (15.5, 12.5 and 19.4 percents respectively). P.pulchellus showed mainly macrophytic vegetation e.g. Chara, Hydrilla, Vallisneria and other plants (31.6, 10.6, 9.6 and 16.9 percents). Labeo fimbriatus had fed on Bacillariophyceae and Chlorophyceae (22.8 and 7.4 percents) and Osteobrama vigorsii on fish and insects (46.8 and 12.9 percents). Of the catfishes, Mystus seenghala and M. aor had 96.1 and 49.9 percents of fish remains with crustaceans and insects (19.3 and 13.1 percents) added. Silanopangasius childrenii showed 72.6 percent fish remains with 9.1 percent insect matter. Pseudeutropius taakree indicated fish, crustaceans and insect matter (18.0, 8.7 and 5.5 percents). Both carps and catfishes obtain adequate food within the reservoir, the catfishes and Osteobrama vigorsii feeding extensively on young fishes, minnow carps and forage fishes.

(8) Only Puntius kolus, P.sarana, Cirrhina reba and Osteobrama vigorsii spawn within the reservoir. All other major and medium forms while attaining maturity go into the river above for breeding.

(9) 81 species of fishes were recognised in the reservoir of which 35 were of commercial value. Bulk of the catches upto 82.2 percent consisted of 12 catfishes which dominated the reservoir. Fish composition by weight in 1965 was Pseudeutropius taakree (23.1 percent), Wallago attu (18.2 percent), Mystus cavasius (12.8 percent) and Mystus aor (11.7 percent). Puntius kolus and P.sarana formed only 3.9 and 2.3 percent each. Major Gangetic species were negligible in number and quantity.

(10) A production of 200.5 and 235.8 metric tons of fishes were estimated to have been produced in 1964 and 1965 respectively. Catch per unit of fishing effort in gill nets was 1.2 to 7.9 kg per month in 1964 and 1.9 to 22.4 kg in 1965 with higher catches during the low water levels between March and June 1965 as fish then became concentrated in Zone IV. Average catches in the 'Alivi' (shore seines) during January to May ranged between 8.05 to 25.50 kg / ha with average daily catches of 40.25 to 127.83 kg per unit. Tungabhadra reservoir is exploited largely by shore seines.

(11) Exploitational experiments by bottom and surface gill nets did not indicate significant differences in the seven centres of the four zones except in sizes and state of maturity of fish, composition being almost similar. Zone III was richer than Zone IV. 40, 45 and 50 mm (bar) nylon nets were invariably more efficient for the species and sizes of fishes available. Bottom set gill nets captured 60.4 percent more number and 70.2 percent more weight of fishes than equivalent surface gill nets.

(12) Study of recruitment of fishes revealed that endemic

commercial forms are recruited during monsoon floods from the river above. Labeo fimbriatus, L. potail and L.porcellus were found in spawn collections in Zone I during 1964 and 1965, besides uneconomical forms. These forms survived in the rich inundated shallow creeks of Zone II and III and gradually disappeared, obviously being preyed upon by the catfishes whose juveniles were being recruited also in large numbers during monsoon floods. An abundant forage fish population consisting of one or more species of Oxygaster, Barilius, Aspidoparia and Puntius exist, which are recruited abundantly during monsoon floods and some of which also spawn in the reservoir more than once during a year.

(13) Stocking by quality fish was inadequate and even the small scale stocking done had substantially enriched the rivers above rather than the reservoir. There was no evidence that any Gangetic carps had spawned above the reservoir.

(14) Suggestions for improvement of composition, stock and exploitational methods as well as management practices within the reservoir, river above and below as well the canals emanating from the dam, are given based upon the empirical data gathered and other findings.