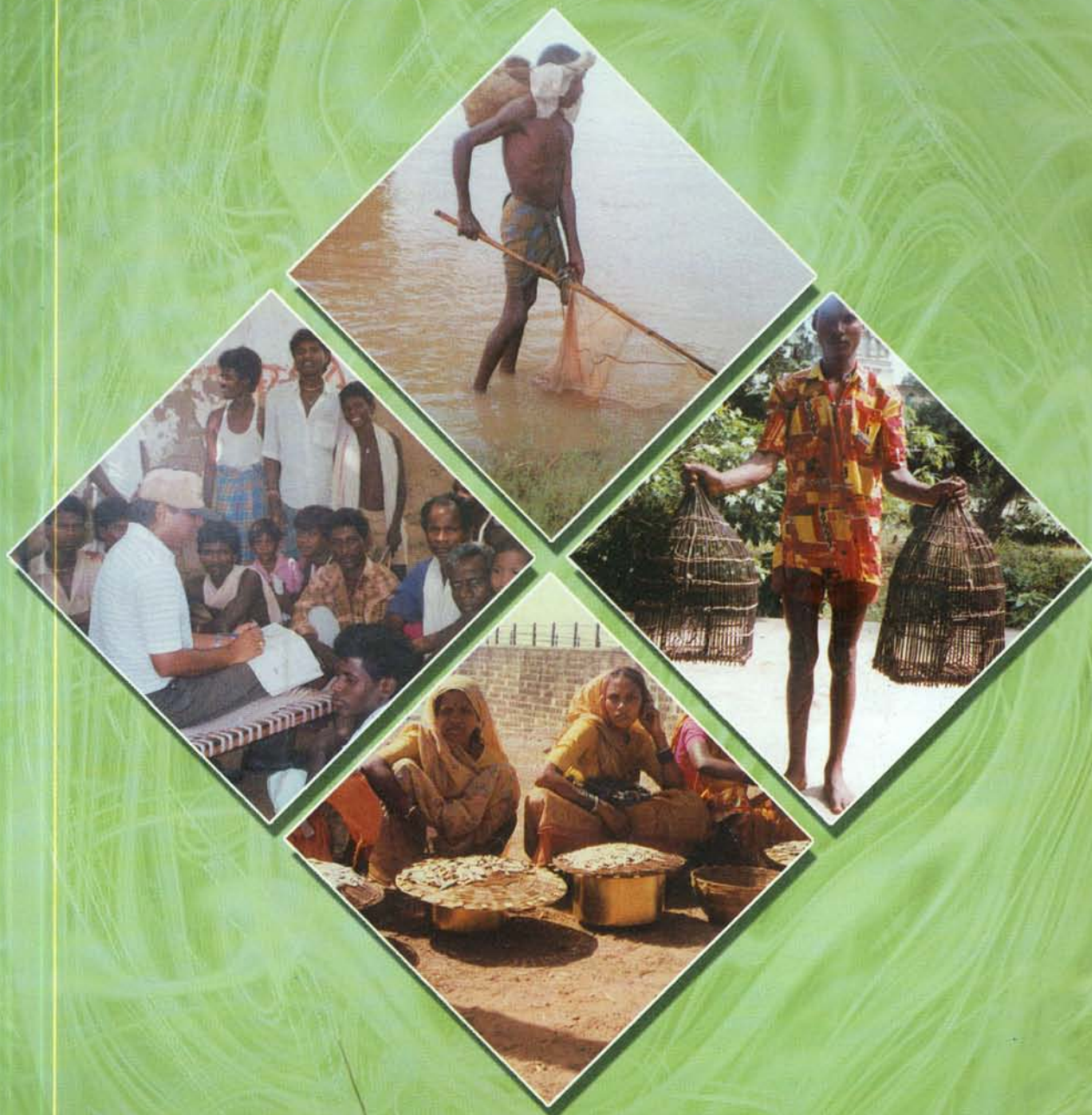


Diamond Jubilee Year
2007

ECOLOGICAL STATUS AND PRODUCTION DYNAMICS OF RIVER MAHANADI



CENTRAL INLAND FISHERIES RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

Barrackpore, Kolkata-700 120, West Bengal, India.

ECOLOGICAL STATUS AND PRODUCTION DYNAMICS OF RIVER MAHANADI

V. Pathak, N. P. Shrivastava, P.K. Chakraborty and A.K. Das

Bull. No. 149



2007

Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore , Kolkata -700120. India

Ecological status and production dynamics of River Mahanadi

ISSN 0970-616 X
@ 2007

Material contained in this bulletin may not be reproduced,
in any form, without the permission of the publisher.

Produced at : The Project Monitoring & Documentation Section,
CIFRI, Barrackpore

Published by : The Director, CIFRI, Barrackpore



Printed at : Graphique International, Kolkata 700 020

FOREWORD

River Mahanadi, travelling a distance of nearly 857 km through Central and Eastern India has diverse ecological features with tremendous fishery potential. The information regarding ecological status and fisheries of this river system is lacking except a few references from some stretches only. Practically, no detailed studies have so far been made on this very important river system. In order to fill up this gap, the Institute took up an exploratory survey of river Mahanadi in relation to its ecology and fisheries covering the entire stretch from origin to sea-mouth.

I am sure that the valuable data thus collected and documented here would give an in-depth information of the Mahanadi system besides providing various conservation measures to protect and improve the fishery of the river.

DIRECTOR

INVESTIGATING TEAM

Upper stretch

Shri N. P. Shrivastava, Principal Scientist

Shri Alok Sarkar, T-6

Shri B. D. Saroj, T-5

Middle stretch

Dr. V. Pathak, Principal Scientist

Dr. Shree Prakash, Principal Scientist

Dr. M. K. Bandyopadhyay, Senior Scientist

Shri L. R. Mahaver, T-5

Shri N. K. Shrivastava, T-5

Lower stretch

Shri P. K. Chakraborty, Principal Scientist

Dr. S. K. Samanta, Senior Scientist

Shri N. N. Mazumdar, T-5

Shri C. P. Singh, T-2

ACKNOWLEDGEMENTS

The cooperation and help received from State Fisheries Departments of Chhattishgarh and Orissa are thankfully acknowledged along with the services of Shri D. Karunakaran, Scientist, CIFRI, Barrackpore for preparing computer graphics of this communication.

CONTENTS

INTRODUCTION	1
THE MAHANADI SYSTEM	1
● The basin	1
● Basin soil	2
● Reservoirs and Deep Pools	2
● Climate	3
Study Area	4
FACTORS INFLUENCING BIOLOGICAL PRODUCTIVITY	5
● Depth & current velocity	5
● Sediment quality	6
● Water quality	9
Biotic variables	15
● Plankton	15
● Macrobenthos	17
● Periphyton	22
● Macrophytes	22
● Aquatic insects	24
ENERGY TRANSFORMATION THROUGH PRIMARY PRODUCTION	25
FISH PRODUCTION POTENTIAL	27
FISH AND FISHERIES	29
● Fish fauna and catch structure	30
● Crafts and gears	36
EXECUTIVE SUMMARY	39

INTRODUCTION

River Mahanadi originates at a height of 660 m above MSL in the Sihawa hills of Kanker basin (20°20' N and 82°30' E) located in the North of Paragon plateau and Bastar Hills at the extreme South West corner of Raipur district near Pharsiya village (Chhattisgarh). It traverses a distance of nearly 857 km before opening into the Bay of Bengal at Paradip (Orissa). The river has a vast drainage area 1,41,589 km², of which nearly 75,042 km² fall in Chhattisgarh, 65,556 km² in Orissa, 708 km² in Bihar and 283 km² in Maharashtra. The river basin offers a large cultivable area of 7994 thousand hectares, of which 51.0%, 48.4%, 0.5% and 0.1% are the shares of different states respectively. From its origin to the sea mouth of the river, more than 78 tributaries get confluenced directly and 22 indirectly, the important among them are Katjuri, Tel, Ong, Ib, Mand, Hasdeo, Tonk, Seonath, Pairi etc. It has a maximum discharge rate of 44,740 million m³ (MCM) and after receiving water (MCM) from various tributaries like Seonath (13,073), Hasdeo (5,389), Tonk (1850), Mand (3,246), Ib (9,003), Ong (2,220) and Tel (11,716) and finally records an annual flow rate of 66,640 MCM at the sea mouth. As the river advances towards sea forming many meanderings on its way, it changes its course sharply more than ten times to provide wider basin area. The most important reservoir constructed across the river is Hirakud near Sambalpur (Orissa) besides a few other reservoirs in the upper stretch.

Ecological status and fisheries of many rivers like Ganga, Narmada, Godavari, Yamuna, Krishna, Ghaghra, Sone, Brahmaputra etc. have been studied by various workers (Bilgrami and Dutta Munshi, 1985; Sinha *et al.*, 1998; Dey, 1999; Khan, 1999; Shankaran Unni, 1996; Karamchandani *et al.*, 1967; Anon, 1997; 1998; 2000; Pathak 1988 & 1999 etc.). But the information regarding the ecology and productivity of river Mahanadi is very limited. Some studies were made on fish and fisheries of the river in selected stretches as early as 1940 (Hora) and 1955 (Job *et. al.*).

Thus, an urgent need was felt to have a detailed knowledge of the ecology and production dynamics of the entire Mahanadi system in order to understand various unknown facts and different ongoing ecological processes. With a view to bridge the gap of knowledge, a detailed exploratory survey of river Mahanadi was conducted from origin to sink during 1996-97. The present communication is the modest attempt in this regard to know the status of present ecological condition of river Mahanadi and its fisheries.

THE MAHANADI SYSTEM

The basin

The river Mahanadi, sandwiched between Sihawa hills in the north of Paragon plateau and Bastar hills in the south-west corner of Raipur district, further moves northwards and slopes down to a height of 300 m asl in the Mahanadi basin. After passing through Bilaspur district before entering Orissa, it continues eastward journey to Hirakud reservoir receiving run-off from Chhuri and Udaipur hills as well as Raigarh and Korba basins. Near Hirakud reservoir, south flowing tributaries bring washings from Sundergarh hills, Himgir and Tharuguda basins. After turning towards south, the river leaves its course through plateau and plains and plunges into the forest and rocky terrains improving its flow through the inflow from the catchment area of Sonabara Plateau, Gandhmardan Parbat and Balangir and Kalahandi basins in the west and Kondamal hills in the south.

The river then makes its way through boulders and sandbars to Sonapur and takes an eastward turn losing its altitude further to 150 m. At this stage the river remains flanked by Tikapara range and Athmallik hills on the left and Kondamal hills in the right. Reaching Dholpur the river

enters the Eastern Ghats and passes through 22.4 km long narrow gorge known as Satkosia gorge. Approaching last laps of its journey through plains it flows between Kanaka hills in the left and Nayagarh hills in the right. The river valley is quite wide (8 km) with alternating flat sandy banks and deeper stiff rocky banks. Again the valley is strewn with boulders, sandbars and anastomosing water courses channels creating many blind alleys of the branching river. Finally, the river enters the deltaic region with extremely shallow sandy beds and a bit deeper muddy stretches besides the tide facing funnel-shaped mouth connected to adjoining estuaries through a few cracks. The river also receives washings from the Malaya Giri.

Basin Soil

The river near origin is composed of silty loam soil, which on moving northwards and eastwards turned into sandy loam and then to a loamy texture. After Hirakud, the river basin has sandy loam and then silty loam soil. Near Sonapur, the river basin comes across clay loam soil. Beyond the Eastern ghat stretch, the basin forms silty loam and then sandy loam in the middle. After Cuttack, the basin soil has only clay loam texture.

Reservoirs and deep pools

The presence of deep pools within the stream is helpful not only for providing shelters to the fishes, especially to the large ones, during dry seasons but also protects them from being washed down with flood waters. Further, such pools reduce the load of pollutants (if any) through dilution and act as silt trap to clear the water flowing through the river. As the river flows down it passes through Dudhawa reservoir near Sihawa and Gangrel reservoir near Dhamtari. Besides these two reservoirs there are seven more on its tributaries till the river reaches Hirakud. The details of nine reservoirs are given in Table 1.

Table 1 : Reservoirs under Mahanadi river system

Name of the reservoir		Location	Catchment area (km ²)	Gross capacity (Mm ³)
1.	Dudhawa	Near Sihawa on Mahanadi	621	288
2.	Ravishankar Sagar (Gangrel)	Near Dhamtari on Mahanadi	3690	909
3.	Murumsilli	On Silyari nadi, a right tributary	484	165
4.	Sondur	On Sondur nadi, a left tributary	512	198
5.	Sikasar	On Pairi river, a right tributary	492	284
6.	Tandula	On Tandula river, a branch of Seonath tributary	827	312
7.	Gondli	On Gondli river, a branch of Seonath tributary	194	102
8.	Kharkhara	On Kharkhara nadi, a branch of Seonath tributary	372	171
9.	Hasdeo	On Hasdeo tributary	6730	3417
10.	Hirakud	On Mahanadi	83400	8316

The formation of dams and barrages has adversely affected the natural flow of the river, which has become shallower at least up to Sirpur. After Sirpur, the river depth increases above one meter and on its way to Hirakud creates a number of deep pools, the details of which are given in Table 2.

Table 2 : Deep pools under Mahanadi river system

Deep pool	Location	Approx. size (m)		
		Length	Width	Depth
1. Malpuri	8 km downstream of Sirpur	1500	100	2
2. Mohan	12 km down of Sirpur	1000	100	2
3. Pindhi	18 km down of Sirpur	1500	100	2
4. Dhamni	30 km down of Sirpur	4000	200	5
5. Parsada	35 km down of Sirpur	1000	100	2
6. Narayanpur	40 km down of Sirpur	2000	150	4
7. Markadi	3 km downstream of Seorinarayan	1000	100	2
8. Pahenda	5 km downstream of Seorinarayan	1000	100	2
9. Paiser	15 km downstream of Seorinarayan	2000	200	4
10. Devarghatta	25 km downstream of Seorinarayan	2000	200	5
11. Jaitpur	8 km downstream of Sarsimha	3000	200	6
12. Chandrapur	At Chandrapur	2000	200	5
13. Pasid	50 km downstream of Chandrapur	4000	300	5

The above thirteen pools locally known as *Dahars* offer great scope for fishing in the area. The Hirakud reservoir extends 80 km in length towards Mahanadi and 50 km towards river Ib but at present it has shrunk. Below Hirakud reservoir, a tortuous pool (11.5-12.0 m deep) forms an important summer resort for many large fishes. The extension of the pool is noticed up to Durgapalli. This stretch of the pool is 4 km and more than 200 m wide with an average depth of 4.5 – 7.5 m. Near Sambalpur, the river is broken into small shallow (1.0-1.5 m) pool like 5-6 km stretches. A narrow pool of 10-13 m deep cut into a wedge-shaped channel through gorge (900 m) and forming good fishing zone exists 2 km downstream of Shankhla. About 56 km downstream of the dam a huge lake like pool (7.5 km²) exists. Abundant shelter and food for fishes are available here. Just above Kamalldhi, near Kutri, a deep pool declared as fish sanctuary is supposed to be largest in Asia. In the downstretch after Baideshwar, the river does not have any deep pool but 3-5 m depth strong current (>5 km hr⁻¹) and sandy bed provide ample scope for fishing activity. The stretch between Mundali barrage and Cuttack barrage a deep pool like condition prevails with low current and depth more than 5 m having sandy bed. The area is productive from fishery point of view.

Climate

Entire river basin comes under > 1000 mm/yr. rainfall zone and moderately warm belt (20.0-32.5°C). The average rainfall during spring, summer and rainy seasons is uniformly 75, 75 and 1000 mm respectively. But during winter it varies from 50 to 250 mm in the upper and middle zone and then to 500 mm in the down stretch. The temperature ranged from 20-25°C during spring, 30.0-32.5°C in summer, 25-30°C during monsoon and less than 25°C in winter season. On an average the lower basin is hit by two major and two minor cyclones annually.

Study Area

A rapid survey of the entire Mahanadi system right from its origin to sea mouth was conducted during 1995-96. The complete river was divided into three stretches.

1. Upper stretch : Origin to Hirakud dam
2. Middle stretch : Durgapalli (Sambalpur) to Narsinghpur
3. Down stretch : Below Narsinghpur to sea mouth

With a view to get year round information, the three stretches were sampled thrice (Post- monsoon, Pre-monsoon and Monsoon seasons). Simultaneous sampling was carried out by three separate teams in these upper, middle and lower stretches of the Mahanadi river systems.

Upper stretch was sampled at twelve sites :

- | | | | |
|-----------------|---------------|-----------------|---------------|
| 1. Sihawa | 2. Dhamtari | 3. Rajim | 4. Chapajhar |
| 5. Belsondha | 6. Sirpur | 7. Seorinarayan | 8. Chandrapur |
| 9. Mahadeopalli | 10. Surajgarh | 11. Chikhli | 12. Tamdei |

Middle stretch was sampled at sixteen sites :

- | | | | |
|---------------|--------------|----------------------|---------------------------|
| 1. Durgapalli | 2. Sambalpur | 3. Taigut or Sankhla | 4. Dhama |
| 5. Laharsara | 6. Binka | 7. Kewatpalli | 8. Sonapur |
| 9. Baunsuni | 10. Baudh | 11. Kurdi | 12. Harbhanga |
| 13. Tikerpara | 14. Kutri | 15. Kokaloba | 16. Narsinghpur (Kakuria) |

Lower stretch was sampled at nine sites :

- | | | | |
|------------|---------------|--------------|---------------|
| 1. Sasang | 2. Baideshwar | 3. Bankigarh | 4. Subarnapur |
| 5. Cuttack | 6. Tirtal | 7. Taldanda | 8. Kujang |
| 9. Paradip | | | |

The three stretches and various sampling centres are shown in Fig. 1.

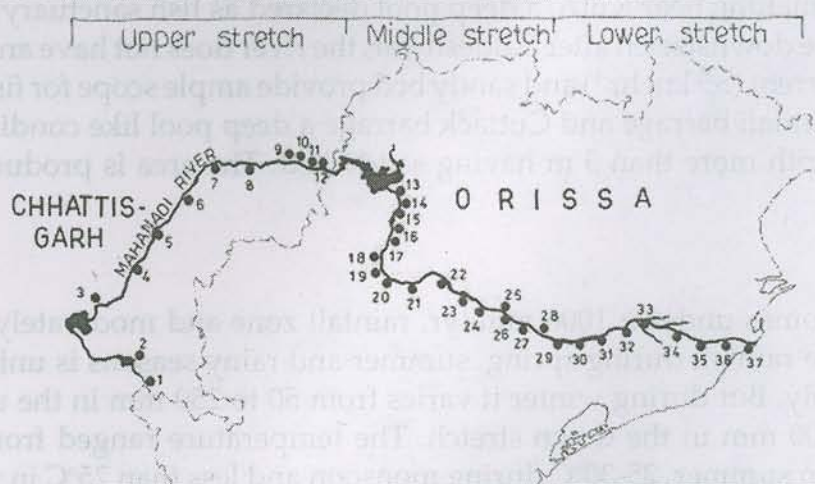


Fig. 1 : Map of River Mahanadi showing different Sampling Centres

* FACTORS AFFECTING BIOLOGICAL PRODUCTIVITY

The biological productivity of any water body mainly depends on its environment. The abundance, distribution and functioning of biotic communities, the production potential and the patterns of energy utilization all depend on the morphometric and edaphic characters. In a fluvial system like rivers the depth, current velocity, siltation rate, sediment and water quality and dynamics of chemical constituents all play key role in the qualitative and quantitative distribution of biotic communities, their whole life cycle and ultimately the final productivity of the system. Thus, in order to evaluate the productivity of the river a critical examination of these variables is the primary requirement.

1. Depth and current velocity
2. Sediment quality
3. Water quality
4. Biotic variables

Depth and Current Velocity

The river system as a whole has an average depth ranging between 2.5 to 5.0 m in different seasons although at some places it had depth less than 0.5 m and high than 15 m. In the upper, middle and lower stretches the minimum and maximum average depths were 94.6 and 733.3 cm; 58.3 and 1270.0 cm; 240.0 and 1000.0 cm respectively.

The details of river depth and water current velocities at different sampling sites are depicted in Table 3.

Table 3 : Water depth and current velocities at different sites of river Mahanadi

Sampling sites	Depth of water (cm)	Current velocity (km hr ⁻¹)
Upper stretch		
Sihawa	94.6	0.70
Dhamtari	245.0	0.00
Rajim	175.0	0.80
Chapajhar	110.0	0.70
Belsondha	191.7	0.70
Sirpur	130.0	0.90
Seorinarayan	241.6	0.60
Chandrapur	333.3	0.80
Mahadeopalli	283.3	0.89
Surajgarh	283.3	0.30
Chikhli	450.0	0.20
Tamdei	733.3	0.18
Average	272.5	0.51

	Middle stretch	
Durgapalli	58.3	Negligible
Sambalpur	84.0	0.480
Sankhla	80.0	1.290
Dhama	195.0	1.735
Laharsara	240.0	1.675
Binka	208.0	1.500
Kewatpalli	207.3	2.123
Sonepur	257.3	1.854
Baunsuni	261.7	2.160
Baudh	166.7	1.536
Kurdi	215.0	1.890
Harbhanga	206.7	1.891
Tikerpara	1270.6	1.905
Kamaladih (Kutri)	293.3	1.665
Kokaloba	240.7	2.247
Narsinghpur	237.0	1.858
Average	263.9	1.613
	Lower stretch	
Sasang	466.7	2.260
Baideshwar	650.0	1.660
Bankigarh	490.0	1.170
Subarnapur	466.7	1.620
Cuttack	266.7	1.100
Tirtal	253.3	1.340
Taldanda	240.0	0.980
Kujang	643.3	1.560
Paradip	1000.0	0.840
Average	497.4	1.390

Current velocity was low in the entire upper stretch (negligible to 0.9 km hr^{-1}). In the middle stretch the velocity except Durgapalli and Sambalpur was in the range of 1.290 to 2.247 km hr^{-1} . In Durgapalli, the current velocity was negligible while in Sambalpur it was 0.48 km hr^{-1} . In the lower stretch, the current velocity was in the range 0.84 to 2.26 km hr^{-1} being minimum in Paradip and maximum in Sasang. The average velocity in the three stretches were 0.51 km hr^{-1} , 1.613 kmhr^{-1} and 1.39 km hr^{-1} respectively.

Sediment Quality

Upper Stretch

The sediment quality of different stations between Sihawa and Tamdei in upper stretch is presented in Table 4. The sediment was dominated by sand 92.0 to 96.0% (av. 93.4%) while the contribution of silt and clay ranged from 2.7 to 5.3% and 1.3 to 3.4% respectively. The percentage of sand was more or less similar in all the stations. Sediment was neutral to alkaline in reaction with pH

- ranging from 7.02 to 7.6 (av. 7.27) and sp. conductance 0.129 to 0.298 mS cm⁻¹ (av. 0.222 mS cm⁻¹). Free calcium carbonate was medium to low ranging from 1.5 to 4.08 %. The nutrient status of the sediment with respect to both available phosphorus (0.59 to 3.88 mg/100g) and nitrogen (2.8 to 10.4 mg/100g) was generally poor with few exceptions. Organic carbon, which is an index of productivity, was also poor to moderate (0.35 to 1.22%), the only exception being Tamdei where it was comparatively higher.

Table 4 : Sediment quality of river Mahanadi in upper stretch

Sampling sites	Physical composition			Chemical composition					
	Sand (%)	Silt (%)	Clay (%)	pH	Sp. cond. (mS cm ⁻¹)	Free CaCO ₃ (%)	Organic carbon (%)	Av. phosphorus (mg/100g)	Av. nitrogen (mg/100g)
Sihawa	94.00	3.50	2.50	7.42	0.256	3.25	0.44	0.59	2.80
Dhamtari	93.30	4.00	2.70	7.60	0.201	4.08	0.41	1.49	7.10
Rajim	94.70	3.00	2.30	7.36	0.230	2.27	0.41	1.23	5.60
Chapajhar	94.30	3.30	2.40	7.23	0.171	1.75	0.41	1.82	7.40
Belsondha	92.70	5.00	2.30	7.22	0.265	1.50	0.53	1.13	5.10
Sirpur	92.00	5.30	2.70	7.26	0.298	2.08	0.61	1.34	5.30
Seorinarayan	94.00	3.30	2.70	7.40	0.254	1.63	0.42	1.29	5.10
Chandrapur	96.00	2.70	1.30	7.15	0.129	1.75	0.35	1.47	6.30
Mahadeopalli	94.30	3.00	2.70	7.04	0.167	2.17	0.51	1.88	6.40
Surajgarh	92.00	5.00	3.00	7.25	0.167	2.42	0.55	3.88	10.40
Chikhli	91.60	5.00	3.40	7.31	0.240	2.67	0.46	1.11	5.50
Tamdei	92.00	5.00	3.00	7.02	0.282	2.50	1.22	1.08	5.30
Average	93.40	4.00	2.60	7.27	0.222	2.34	0.53	1.53	6.02

Middle Stretch

The sediment quality at different stations between Durgapalli and Narsinghpur in the middle stretch of the river is presented in Table 5. Like the upper stretch sand remained the dominant component 94.0 to 99.0 % (av. 97.5%) with silt and clay contributing 0.4 to 4.0% (av. 1.75%) and 0.0 to 2.0% (0.75%) respectively. The percentage composition of all the three physical components remained almost same in the entire stretch with few exceptions. Sediment was near neutral in reaction with pH ranging from 6.7 to 7.2 (av. 7.0) and sp. conductance 0.047 to 0.093 mS cm⁻¹ (av. 0.069 mS cm⁻¹). The values of conductance were comparatively much lower in this stretch (68.7 mS cm⁻¹) when compared to those in the upper stretch (221.7 mS cm⁻¹). The available nutrients, phosphorus, (0.62 to 1.05 mg/100g) and nitrogen (4.8 to 7.6 mg/100g) were poor throughout the stretch. Organic carbon, which reflects the productivity of sediment was also poor to moderate (0.34 to 0.69%). Free calcium carbonate remained low in the entire stretch (1.0 to 2.62%). It needs to be mentioned that the river is flowing through hills and forest in this stretch and as a result it must be carrying large amount of organic carbon by the influx of water through catchment area but due to high contribution of sand (av. 97.5%) the materials brought could not be retained in the sediment for longer period as being washed out. Similar observations have also been made in many other rivers.

Table 5 : Sediment quality of river Mahanadi in middle stretch

Sampling sites	Physical composition			Chemical composition					
	Sand (%)	Silt (%)	Clay (%)	pH	Sp. cond. (mS cm ⁻¹)	Free CaCO ₃ (%)	Organic carbon (%)	Av. phosphorus (mg/100g)	Av. nitrogen (mg/100g)
Durgapalli	97.00	2.00	1.00	7.00	0.089	2.62	0.60	0.82	6.70
Sambalpur	96.00	2.50	1.50	6.70	0.061	1.00	0.69	1.30	7.40
Shankhala	98.50	1.00	0.50	7.00	0.621	2.15	0.34	0.71	6.00
Dhama	97.00	2.50	0.50	6.90	0.049	1.22	0.37	0.71	6.00
Laharsara	99.00	0.50	0.50	7.10	0.054	1.47	0.43	0.71	6.50
Binka	99.00	1.00	0.00	7.10	0.094	1.35	0.51	0.69	6.80
Keotpalli	97.00	2.00	1.00	7.10	0.062	1.87	0.49	0.76	5.80
Sonepur	97.00	2.50	0.50	7.00	0.077	1.92	0.46	0.71	5.50
Baunsuni	98.00	1.00	1.00	7.00	0.054	1.55	0.40	0.62	4.90
Baudh	98.00	1.50	0.50	7.00	0.077	1.92	0.46	0.71	5.50
Kurdi	98.00	1.00	1.00	7.00	0.077	1.92	0.46	0.71	5.50
Harbhanga	98.00	2.00	0.00	7.10	0.069	2.07	0.49	0.70	4.80
Tikerpara	94.00	4.00	2.00	7.20	0.078	2.35	0.48	0.71	5.20
Kutri	99.00	0.50	0.50	6.90	0.074	1.97	0.39	0.66	5.50
Kokaloba	98.00	1.50	0.50	6.70	0.076	1.87	0.48	1.05	7.60
Narsinghpur	96.00	2.50	1.50	7.00	0.047	1.12	0.45	0.85	7.30
Average	97.50	1.75	0.75	7.00	0.069	1.75	0.46	0.79	6.10

Lower Stretch

The sediment quality parameters at different stations of the river are presented in Table 6. Sediment in this stretch also was dominated by sand, 79.7 to 92.0% (av. 85.8%) with silt and clay ranging between 1.3 to 8.3% (av. 5.4%) and 4.3 to 13.9% (av. 8.8%) respectively. The clay content was comparatively higher in this stretch when compared to upper and lower stretches with corresponding decline in sand. Sediment was generally alkaline in reaction in this stretch with pH ranging from 7.2 to 8.03, the only exception being Kujang where the pH was slightly towards acidic side (pH 6.79). The sp. conductance of sediment ranged from 0.077 to 0.168 mS cm⁻¹ between Sasang and Taldanda but in Kujang and Paradip, it was as high as 0.690 to 3.200 mS cm⁻¹ reflecting the estuarine character of the river. Free calcium carbonate was low in all the stations ranging from 0.53 to 1.07%. Both the available nutrients were comparatively more, nitrogen 6.27 to 16.6 mg/100g (av. 10.3 mg/100g) and phosphorus 0.61 to 2.97 mg/100g (av. 1.68 mg/100g) respectively. In fact, the phosphorus content was slightly better than the other stretches with values sometimes going up to 5.39 mg/100g, even available nitrogen was 23.0 mg/100g at times. The organic carbon was invariably low in this stretch also 0.178 to 0.537%. In fact, the carbon content was comparatively lower in this stretch (av. 0.308%) than the other two stretches.

In general the soil texture of the entire river was sandy except some stations of the lower stretch where the clay content was comparatively high. From large number of observations it has been

found that slightly alkaline soils with pH 7.5 to 8.5, available nitrogen between 25.0 to 75.0 mg/100g or more, available phosphorus 3 to 6 mg/100g or more and organic carbon more than 1% are considered to be productive. If these values of productive soils are compared with the value observed in Mahanadi it can be concluded that the river is low productive in respect of organic carbon and available nutrients. But in such flowing systems the role of catchment becomes more important and the flora and fauna are mainly supported by the status of the catchment rather than the sediment alone.

Table 6 : Sediment quality of river Mahanadi in lower stretch

Sampling sites	Physical composition			Chemical composition					
	Sand (%)	Silt (%)	Clay (%)	pH	Sp. cond. (mS cm ⁻¹)	Free CaCO ₃ (%)	Organic carbon (%)	Av. phosphorus (mg/100g)	Av. nitrogen (mg/100g)
Sasang	87.70	6.20	6.10	7.74	0.084	0.60	0.22	1.64	7.93
Baideshwar	83.80	5.50	10.70	7.51	0.100	0.94	0.32	1.97	10.27
Bankigarh	77.80	8.30	13.90	7.91	0.167	1.07	0.54	2.20	16.60
Subarnapur	85.00	5.20	9.80	7.70	0.085	0.86	0.43	2.97	11.87
Cuttack	90.50	4.20	5.30	8.02	0.123	1.01	0.32	0.61	6.73
Tirtal	92.00	3.70	4.30	7.20	0.091	0.53	0.23	0.99	9.20
Taldanda	84.80	6.50	8.70	7.40	0.077	0.76	0.35	2.26	10.47
Kujang	79.70	7.70	12.60	6.79	0.690	0.91	0.41	1.17	13.33
Paradip	91.20	1.30	7.50	8.03	3.200	0.60	0.18	1.27	6.27
Average	85.80	5.40	8.80	7.59	0.513	0.81	0.31	1.68	10.30

Water Quality

Upper Stretch

The water quality parameters between Sihawa and Tamdei in the upper stretch are presented in Table 7. Among the physical parameters, water temperature was almost same with minor fluctuations (24.7 to 30.2°C) being maximum in Sihawa and minimum in Mahadeopalli. The other parameters, transparency, on which the penetration of light or euphotic zone depends ranged from 30.3 to 158.0 cm. Water was more clear between Sihawa and Seorinarayan (80.0 to 152.0 cm) and then transparency dropped suddenly at Tamdei, the water transparency increased sharply (158.0 cm) at Chandrapur reaching minimum at Mahadeopalli. Again at Tamdei, the water transparency increased sharply (158.0cm). In fact, water was transparent up to bottom on many occasions and the entire column was under euphotic zone. Water was alkaline in reaction throughout the stretch with pH ranging from 8.07 to 8.46. Maximum pH was observed at Dhamtari while minimum was at Mahadeopalli. Among the dissolved gases free carbon dioxide was absent on many occasions and when present its value ranged between 0.32 and 1.26 mg/l⁻¹. Dissolved oxygen was quite rich throughout the stretch with average values ranged from 6.3 to 8.45 mg/l⁻¹ (av. 7.36 mg/l⁻¹). Total alkalinity, conductance and dissolved solids all were reasonably high throughout the stretch with values ranging from 66.8 to 146.2 mg/l⁻¹, 132 to 322 mS cm⁻¹ and 68.0 to

164.0 mg l⁻¹ respectively. All the parameters were maximum at the origin point Sihawa, which showed sudden drop at Dhamtari, the next station. An increasing trend although of lesser magnitude was observed up to Seorinarayan and then declined reaching minimum at Mahadeopalli. Among the other chemical parameters calcium, magnesium and hardness ranged from 13.42 to 33.85 mg l⁻¹ (av. 20.32 mg l⁻¹), 5.78 to 10.67 mg l⁻¹ (av. 8.59 mg l⁻¹) and 60.7 to 128.3 mg l⁻¹ (av. 86.3 mg l⁻¹) respectively. The zonal variation in all the three parameters followed the same pattern as that of alkalinity. Water showed comparatively much concentration of chloride in this stretch 32.70 to 42.46 mg l⁻¹ (av. 36.9 mg l⁻¹). Maximum chloride was observed at the origin Sihawa and minimum at Tamdei with an overall declining trend from upper to lower stations with few exceptions. Though sediment was poor in organic carbon, water showed comparatively much higher values of dissolved organic matter 0.98 to 1.23 mg l⁻¹ (av. 1.11 mg l⁻¹).

Table 7 : Physico-chemical characteristics of water in river Mahanadi (upper stretch)

Sampling sites	Temp. (°C)	Transp. (cm)	pH	Sp.cond. (µS cm ⁻¹)	DO (mg l ⁻¹)	CO ₂ (mg l ⁻¹)	Alkalinity (mg l ⁻¹)	TDS (mg l ⁻¹)	Ca ⁺⁺ (mg l ⁻¹)	Mg ⁺⁺ (mg l ⁻¹)	Hardness (mg l ⁻¹)	Chloride (mg l ⁻¹)	DOM (mg l ⁻¹)
Sihawa	30.20	152.00	8.10	321	6.44	0.63	146.20	164.00	33.85	10.38	128.30	42.46	1.18
Dhamtari	28.70	80.00	8.46	158	7.30	0.00	73.70	78.60	18.10	6.21	68.70	38.70	1.14
Rajim	27.30	140.00	8.03	170	7.00	1.26	76.20	84.00	15.54	5.93	63.30	38.70	1.02
Chapajhar	27.30	128.40	8.20	192	7.50	0.32	88.70	96.20	18.96	10.67	91.50	38.60	1.09
Belsondha	27.60	130.20	8.16	194	6.30	0.63	89.30	98.00	24.30	5.78	84.30	37.60	1.17
Sirpur	26.70	148.00	8.23	184	7.58	0.91	85.60	92.80	19.80	8.50	86.30	34.30	1.04
Seorinarayan	26.50	112.80	8.10	242	7.65	0.63	113.10	124.00	24.27	10.05	102.20	40.20	0.98
Chandrapur	26.30	31.70	8.20	164	7.57	0.63	81.40	82.00	18.28	10.30	89.90	35.20	1.23
Mahadeopalli	24.70	30.30	8.07	132	7.69	0.91	66.80	68.00	13.42	6.56	60.70	32.70	1.04
Surajgarh	26.00	44.70	8.10	182	17.37	0.91	81.90	92.00	16.60	9.67	81.40	37.60	1.06
Chikhli	27.70	59.00	8.13	198	7.62	0.91	89.70	99.00	21.08	10.04	94.24	35.70	1.13
Tamdei	26.90	158.00	8.10	192	8.45	0.91	84.40	96.00	19.16	8.87	84.60	32.70	1.19
Average	27.12	101.26	8.15	194	7.36	0.74	89.77	97.80	20.32	8.59	86.30	36.90	1.11

TDS= Total dissolved salt; DOM= Dissolved organic matter

Middle Stretch

Water quality of river between Durgapalli and Narsinghpur in the middle stretch has been presented in the Table 8. Temperature showed only minor fluctuation in the entire stretch (25.0 to 28.0°C). Clarity of water reflecting the extent of light penetration was of higher order with Secchi depth ranged from 63.5 cm (Kurdi) to 122.7 cm (Sonepur) with an average of 89.7 cm. On many occasions water was found to be transparent up to bottom. The station-wise variation did not show any regular trend. Water was always alkaline in reaction with pH ranging from 7.7 to 8.0 (av. 7.8) but the value of pH in this stretch was comparatively lower than the upper stretch. Among the dissolved gases, free carbon dioxide was found to be absent on many occasions and if present it varied from 0.32 to 1.86 mg l⁻¹ (av. 0.88 mg l⁻¹), while oxygen was in the range 7.2 to 9.6 mg l⁻¹ (av. 8.0 mg l⁻¹). Total alkalinity, conductance and total dissolved solids were quite high with values ranged at 63.0 to 77.0 mg l⁻¹ (av. 69.9 mg l⁻¹), 1481 to 1785 mS cm⁻¹ (av. 165 mS cm⁻¹) and 73.8 to 88.3 mg l⁻¹ (av. 82.4 mg l⁻¹) respectively. Although these parameters did not show much variations between the stretches, but an increasing trend could be observed from upstream to down stretch with minimum at Sambalpur and maximum at Narsinghpur. Among other chemical parameters calcium, magnesium and total hardness ranged from 16.1 to 21.6 mg l⁻¹, 3.8 to 6.7 mg l⁻¹ and 60.2 to 78.7 mg l⁻¹ respectively. Silicate and chloride ranged from 6.4 to 9.0 mg l⁻¹ (av. 7.1 mg l⁻¹) and 23.8 to

30.6 mg l⁻¹ (av. 26.2 mg l⁻¹) respectively with no definite trend of variations between inter-stations. Chloride content in the middle stretch was comparatively lower than upper stretch. The dissolved organic matter was quite high in the entire stretch ranged between 1.13 and 1.69 mg l⁻¹ (av. 1.26 mg l⁻¹) inspite of the low values of organic carbon in the sediment phase. as well as the nutrient status of water in respect of nitrate (0.022 to 0.078 mg l⁻¹) and phosphate (0.003 to 0.005 mg l⁻¹) in this stretch also.

Table 8 : Physico-chemical characteristics of water of river Mahanadi (middle stretch)

Sampling sites	Temp (°C)	Transp. (cm)	pH	Sp.cond. (µS cm ⁻¹)	DO (mg l ⁻¹)	CO ₂ (mg l ⁻¹)	Alkalinity (mg l ⁻¹)	TDS (mg l ⁻¹)	Ca ⁺⁺ (mg l ⁻¹)	Mg ⁺⁺ (mg l ⁻¹)	Hardness (mg l ⁻¹)	Chloride (mg l ⁻¹)	DOM (mg l ⁻¹)
Durgapalli	26.20	79.50	7.60	154	8.00	1.86	66.00	78.80	16.10	5.70	64.00	24.51	1.79
Sambalpur	26.30	82.00	7.80	148	7.20	0.63	63.00	73.80	16.60	4.50	60.20	29.41	1.60
Shankhala	26.00	83.00	7.80	157	7.30	0.63	64.30	78.10	18.10	5.40	60.80	26.14	1.60
Dhama	26.20	109.70	7.80	157	7.90	0.93	67.10	78.10	17.40	5.37	60.30	26.70	1.88
Laharsara	26.00	92.70	7.80	155	7.60	0.62	64.30	77.20	15.33	6.52	59.20	27.80	1.74
Binka	26.20	88.50	7.80	163	7.60	0.93	69.00	82.20	17.24	4.22	64.70	24.60	1.54
Keotpalli	26.70	99.00	8.00	163	7.50	1.00	69.40	81.20	18.20	6.52	67.60	27.80	1.60
Sonepur	26.50	122.30	7.80	165	7.60	0.93	70.50	82.50	17.80	6.78	71.00	27.70	1.71
Baunsuni	25.70	78.50	7.80	165	7.80	0.72	70.60	82.80	18.52	4.80	64.50	29.40	1.55
Baudh	25.00	110.80	7.80	176	8.20	0.52	74.80	87.90	18.68	6.90	71.80	31.80	1.93
Kurdi	26.30	63.50	7.30	166	7.20	1.28	68.10	83.40	18.68	6.75	69.10	34.31	1.48
Harbhanga	25.30	73.70	7.70	173	7.90	1.25	74.70	86.80	20.74	5.37	74.70	29.40	1.67
Tikerpara	27.00	98.00	7.90	171	7.80	0.63	73.50	86.30	18.52	6.52	71.80	27.80	1.59
Kutri	28.20	76.00	8.00	109	7.90	0.32	73.00	84.40	19.80	6.13	69.30	27.80	1.59
Kokaloba	28.00	83.30	7.90	171	7.90	0.63	73.50	84.60	18.51	8.06	73.30	29.40	1.64
Narsinghpur	26.20	94.00	7.80	178	7.70	1.24	77.00	88.30	19.16	7.70	78.70	29.40	1.71
Average	26.20	89.70	7.80	165	8.00	0.88	69.90	82.40	18.00	6.07	67.60	28.37	1.67

Lower Stretch

The water quality parameters of river Mahanadi between Sasang and Paradip in the lower stretch are presented in Table 9. The water temperature ranged from 28.5 to 30.3°C with minor fluctuations. The transparency of water was comparatively higher in the stretch between Sasang and Taldanda with Secchi depth ranged from 62.1 to 84.9 cm. In the stretch between Kujang and Paradip, transparency showed sudden drop to 35.6 and 47.6 cm. Water was always alkaline in reaction with pH varied between 8.04 and 8.26 and the values were similar in the entire stretch. Among the dissolved gases, oxygen was quite rich in the entire lower stretch with the values ranged between 6.7 and 7.9 mg l⁻¹ while free carbon dioxide remained absent on many occasions and if present, it ranged from 0.5 to 0.8 mg l⁻¹. Alkalinity values fluctuated between 71.5 and 86.7 mg l⁻¹ with slight increase in the down stretch. Other water quality parameters including conductance, dissolved solids, calcium, magnesium and total hardness ranged from 169 to 188 mS cm⁻¹, 84.0 and 93.4 mg l⁻¹, 16.55 to 17.69 mg l⁻¹, 4.5 to 4.89 mg l⁻¹ and 60.1 to 63.5 mg l⁻¹ respectively in the stretch between Sasang to Taldanda.

Table 9 : Physico-chemical characteristics of water in river Mahanadi (lower stretch)

Sampling sites	Temp (°C)	Transp. (cm)	pH	Sp.cond. ($\mu\text{S cm}^{-1}$)	DO (mg l^{-1})	CO ₂ (mg l^{-1})	Alkalinity (mg l^{-1})	TDS (mg l^{-1})	Ca ⁺⁺ (mg l^{-1})	Mg ⁺⁺ (mg l^{-1})	Hardness (mg l^{-1})	Chloride (mg l^{-1})
Sasang	28.60	84.90	8.20	170	7.30	0.60	71.50	84	16.62	4.56	60.30	4.00
Baideshwar	28.70	65.70	8.19	173	7.70	0.80	76.50	86	16.82	4.50	60.50	5.30
Bankigarh	29.00	62.10	8.26	169	7.30	0.66	72.60	84	16.55	4.56	60.10	4.30
Subarnapur	29.50	74.00	8.16	176	7.60	0.66	74.50	87	16.88	4.68	61.40	3.70
Cuttack	29.50	62.30	8.23	181	7.30	0.50	73.30	90	17.39	4.54	62.10	5.50
Tirtal	30.80	66.00	8.22	185	7.90	0.50	79.50	92	17.69	4.89	64.30	7.33
Taldanda	30.30	69.00	8.25	188	7.50	0.60	80.00	93	17.42	4.87	63.50	10.00
Kujang	29.50	35.60	8.04	9468	6.90	0.60	86.20	4696	87.30	235.07	1185.30	3515.00
Paradip	28.50	47.60	8.13	21994	6.70	0.00	86.70	10909	151.80	557.50	2665.80	82983.00
Average	29.38	63.02	8.19	177*	7.35	0.54	77.87	88*	17.05*	4.66*	61.74	5.73*

* Excluding the values at Kujang & Paradip

Nutrient Status of Water in River Mahanadi

Among dissolved nutrients, nitrate and phosphate have been widely studied and their role and importance in aquatic productivity have been well recognized. Dissolved inorganic nitrogen in the range of 0.20 to 0.50 mg l^{-1} may be considered favourable for fish productivity of which ammonium and nitrate forms constitute the readily available source of nitrogen to fish food organisms. Soluble reactive phosphorus in water in the form of phosphate for maintaining aquatic productivity ranges from 0.05 to 0.20 mg l^{-1} . Silicate is the available form of silicon in natural waters and acts as structural constituent of diatoms and many sponges.

In the upper stretch, nutrient status of water (Table 10) was very poor with nitrate and phosphate values in the range 0.022 to 0.047 mg l^{-1} and 0.002 to 0.009 mg l^{-1} respectively. However, Silicate-silicon was moderate and more or less similar in all the stations with little fluctuations (5.7 to 7.3 mg l^{-1}).

Table 10 : Nutrient status of water of river Mahanadi (upper stretch)

Sampling sites	Nitrate-N (mg l^{-1})	Phosphate-P (mg l^{-1})	Silicate-Si (mg l^{-1})
Sihawa	0.030	0.009	7.30
Dhamtari	0.021	0.004	5.70
Rajim	0.021	0.006	6.50
Chapajhar	0.021	0.007	6.00
Belsondha	0.022	0.007	6.10
Sirpur	0.038	0.003	6.00
Seorinarayan	0.038	0.002	6.40
Chandrapur	0.022	0.002	5.70
Mahadeopalli	0.036	0.002	6.80
Surajgarh	0.047	0.002	6.00
Chikhli	0.048	0.004	6.10
Tamdei	0.045	0.004	5.70
Average	0.034	0.004	6.19

In the middle stretch, Silicate ranged from 6.4 to 9.0 mg l^{-1} (av. 7.1 mg l^{-1}) with no definite trend of variations between inter-stations. Nutrient status of water in respect of nitrate (0.022 to 0.078 mg l^{-1}) and phosphate (0.003 to 0.005 mg l^{-1}) in this stretch also was poor (Table 11).

Table 11 : Nutrient status of water of river Mahanadi (middle stretch)

Sampling sites	Nitrate-N (mg l^{-1})	Phosphate-P (mg l^{-1})	Silicate-Si (mg l^{-1})
Durgapalli	0.020	0.002	5.80
Sambalpur	0.045	0.003	5.90
Shankhala	0.055	0.005	6.00
Dhama	0.030	0.005	6.00
Laharsara	0.120	0.003	5.80
Binka	0.030	0.003	6.47
Keotpalli	0.020	0.002	6.70
Sonepur	0.030	0.003	6.60
Baunsuni	0.073	0.005	8.30
Baudh	0.047	0.002	6.50
Kurdi	0.070	0.025	6.30
Harbhanga	0.026	0.004	6.80
Tikerpara	0.047	0.003	6.73
Kutri	0.050	0.003	6.40
Kokaloba	0.060	0.003	6.53
Narsinghpur	0.030	0.003	6.70
Average	0.043	0.004	6.50

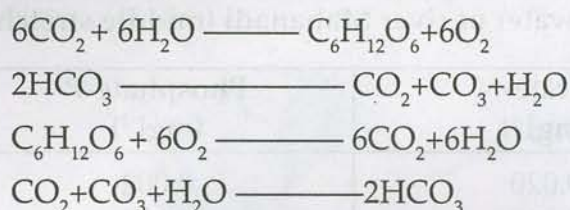
In the lower stretch, concentration of dissolved nutrients in water (Table 12) was improved upon compared to other two stretches in the upstream. Nitrate-N and phosphate-P fluctuated to the tune of 0.000 to 0.110 and 0.003 to 0.011 mg l^{-1} respectively while silicate-Si ranged between 8.00-15.64 mg l^{-1} in this lower stretch of river Mahanadi.

Table 12 : Nutrient status of water of river Mahanadi (lower stretch)

Sampling sites	Nitrate-N (mg l^{-1})	Phosphate-P (mg l^{-1})	Silicate-Si (mg l^{-1})
Sasang	0.053	0.006	13.20
Baideshwar	0.016	0.005	12.96
Bankigarh	0.055	0.010	12.89
Subarnapur	0.063	0.003	12.81
Cuttack	0.080	0.006	12.84
Tirtal	0.110	0.011	15.64
Taldanda	0.040	0.008	15.20
Kujang	0.000	0.008	10.90
Paradip	0.067	0.007	8.00
Average	0.053	0.007	12.71

Dynamics of Chemical Parameters

The dynamics of chemical constituents in any aquatic ecosystem is reflected in the diurnal variation. The reactions taking place in the two phases of the day are:



As a result of the light reactions during day time the water body observes a gradual increase in oxygen due to its production, decline in bicarbonate and increase in carbonate and pH. On the other hand, due to the impact of dark reaction in the night, the water body shows a gradual decrease in dissolved oxygen owing to its consumption, increase of bicarbonate and decrease in carbonate and pH. The quantitative assessment of the changes brought out by these two opposing processes can be used to evaluate the productivity of the aquatic system as the cycle are directly linked with the production and consumption processes. In fact, the diel cycle of chemical parameters especially dissolved oxygen has been used for the classification of different ecosystems in terms of productivity.

Diurnal studies were made in three stretches of river Mahanadi at six hourly basis and a pooled data of the three stretches have been presented in Table 13. Water temperature showed an increase of 11°C, 7.4°C and 7.2°C in the upper, middle and lower stretches respectively while dissolved oxygen (mg l^{-1}) showed an increase of 4.1, 3.1 and 3.7 in the three stretches during day time. Similarly, pH and carbonate also showed an increase of 0.8 and 15.0 mg l^{-1} in the upper stretch, 0.6 and 5.5 mg l^{-1} in the middle and 2.0 and 5.5 mg l^{-1} in the lower stretch respectively. On the contrary, bicarbonate (mg l^{-1}) showed a variation of 44.3, 22.3 and 25.9 respectively with the progress of the day and sharp declining trend was observed during night time. Free carbon dioxide was generally absent in the upper and middle stretch and a slight declining trend was observed only once in the lower stretch. The magnitude of diel change showed considerable spatio-temporal variations. The intensity was higher where the water was more static with feeble current. On some occasions, the change was very sharp due to favourable conditions. If the intensity of variations in different stretches was used to evaluate the relative productivity of the Mahanadi as a whole, it could be rightly pointed out that upper stretch, where the fluctuations were more in chemical parameters was more productive compared to the other two stretches. The diurnal change in the chemical parameters got reflected in the diurnal occurrence of plankton, which showed a fluctuation of 48 ul^{-1} in the upper stretch, 168 ul^{-1} in the middle and 169 ul^{-1} in the lower stretch.

Table 13 : Diel cycle of abiotic and biotic parameters of water in Mahanadi

Parameters	Upper stretch		Middle stretch		Lower stretch	
	Range of fluctuation	Magnitude	Range of fluctuation	Magnitude	Range of fluctuation	Magnitude
Water temp. (°C)	20.3-31.3	11.0	23.8-31.2	7.4	24.6-31.8	7.2
DO (mg l^{-1})	5.1-9.2	4.1	6.2-9.3	3.1	4.8-8.5	3.7
pH	7.9-8.7	0.8	7.5-8.1	0.6	6.8-8.6	2.0
Free CO_2 (mg l^{-1})	Nil	Nil	Nil	Nil	1.4-2.5*	1.1*

Parameters	Upper stretch		Middle stretch		Lower stretch	
	Range of fluctuation	Magnitude	Range of fluctuation	Magnitude	Range of fluctuation	Magnitude
Carbonate (mg l ⁻¹)	2.2-17.2	15.0	2.5-8.0	5.5	5.0-10.5**	5.5**
Bicarbonate (mg l ⁻¹)	47.9-96.4	44.3	60.0-82.3	22.3	64.8-90.7	25.9
Plankton (ul ⁻¹)	69-117	48	95-263	168	118-287	169

* In one season only

** Average of two seasons

Biotic Variables

Plankton

As seen from the overall values, the plankton population fluctuated in a narrow range 106-136 ul⁻¹ in all three stretches of river Mahanadi. Higher concentration of plankton was noticed at some of the centres like Harbhanga (598 ul⁻¹), Kurdi (581 ul⁻¹) and Tamdei (512 ul⁻¹). Plankton was poor during monsoon in all the three sectors as compared to pre- and post-monsoon periods (Fig. 2).

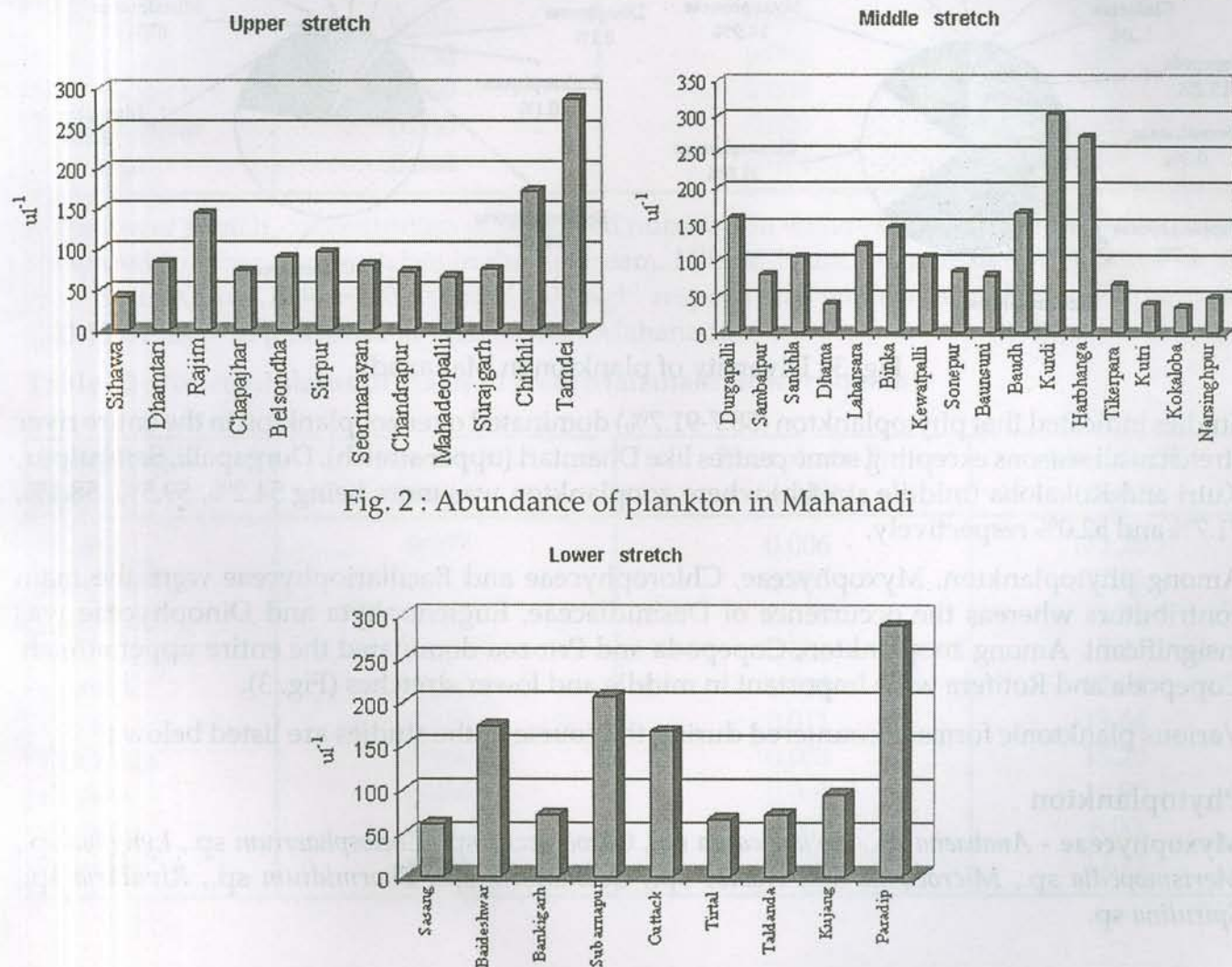
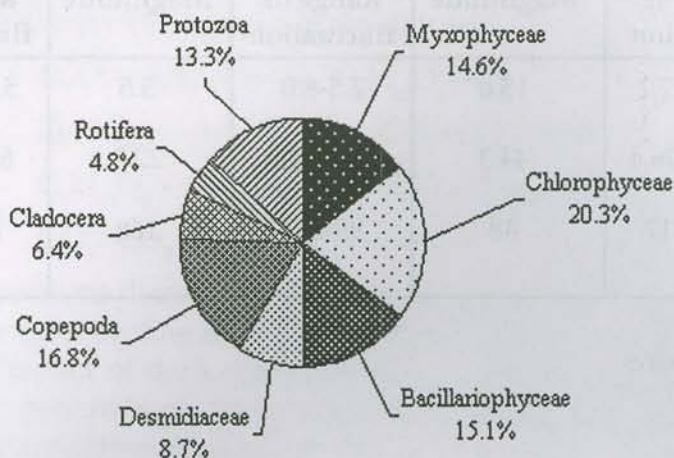
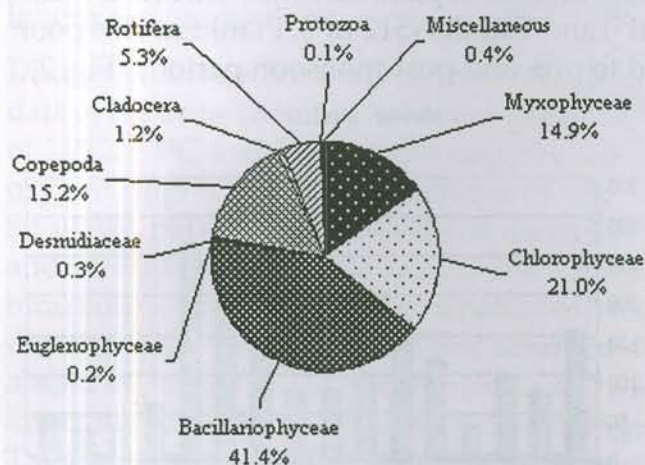


Fig. 2 : Abundance of plankton in Mahanadi

Upper stretch



Middle stretch



Lower stretch

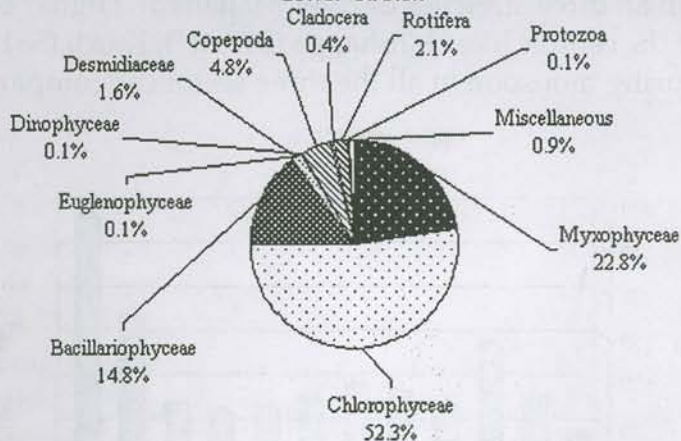


Fig. 3 : Diversity of plankton in Mahanadi

Studies indicated that phytoplankton (58.7-91.7%) dominated over zooplankton in the entire river stretch in all seasons excepting some centres like Dhamtari (upper stretch), Durgapalli, Sambalpur, Kutri and Kokaloba (middle stretch) where zooplankton was more being 54.2%, 59.5%, 58.1%, 71.7% and 52.0% respectively.

Among phytoplankton, Myxophyceae, Chlorophyceae and Bacillariophyceae were the main contributors whereas the occurrence of Desmidiaceae, Euglenophyta and Dinophyceae was insignificant. Among zooplankton, Copepoda and Protozoa dominated the entire upper stretch. Copepoda and Rotifera were important in middle and lower stretches (Fig. 3).

Various planktonic forms encountered during the course of the studies are listed below :

Phytoplankton

Myxophyceae - *Anabaena* sp., *Aphanocapsa* sp., *Chroococcus* sp., *Coelosphaerium* sp., *Lyngbya* sp., *Merismopedia* sp., *Microcystis* sp., *Nostoc* sp., *Oscillatoria* sp., *Phormidium* sp., *Rivularia* sp., *Spirulina* sp.

Desmidiaceae - *Closterium* sp., *Cosmarium* sp., *Desmidium* sp., *Genicularia* sp., *Gonatozygon* sp., *Netrium* sp., *Penium* sp., *Spirotaenia* sp., *Spondylosium* sp., *Staurastrum* sp., *Triploceras* sp.

Bacillariophyceae - *Amphora* sp., *Anomoeneis* sp., *Asterionella* sp., *Bacillaria* sp., *Chaetoceras* sp., *Cocconeis* sp., *Coscinodiscus* sp., *Cyclotella* sp., *Cymatopleura* sp., *Cymbella* sp., *Diatoma* sp., *Diploneis* sp., *Fragilaria* sp., *Frustulia* sp., *Gomphoneis* sp., *Gomphonema* sp., *Gyrosigma* sp., *Hydrocera* sp., *Mastogloia* sp., *Melosira* sp., *Meridion* sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Pleurosigma* sp., *Rhopalodia* sp., *Surriella* sp., *Synedra* sp., *Tabellaria* sp.

Euglenophyceae - *Euglena* sp., *Phacus* sp.

Dianophyceae - *Ceratium* sp., *Peridinium* sp.

Chlorophyceae - *Ankistrodesmus* sp., *Binuclearia* sp., *Botryococcus* sp., *Chaetophora* sp., *Chlamydomonas* sp., *Cladophora* sp., *Coelastrum* sp., *Enteromorpha* sp., *Eudorina* sp., *Golenkinia* sp., *Kirchneriella* sp., *Microspora* sp., *Oedogonium* sp., *Pediastrum* sp., *Pithophora* sp., *Protococcus* sp., *Rhizoclonium* sp., *Scenedesmus* sp., *Spirogyra* sp., *Stigeoclonium* sp., *Tetraspora* sp., *Treubaria* sp., *Tribonema* sp., *Trochiscia* sp., *Ulothrix* sp., *Volvox* sp., *Zygnema* sp.

Zooplankton

Copepoda - *Cyclops* sp., *Diaptomus* sp., Copepod nauplii

Cladocera - *Alona* sp., *Alonella* sp., *Bosmina* sp., *Ceriodaphnia* sp., *Chydorus* sp., *Daphnia* sp., *Diphanosoma* sp., *Leydigia* sp., *Limnocalanus* sp., *Moina* sp., *Sida* sp.

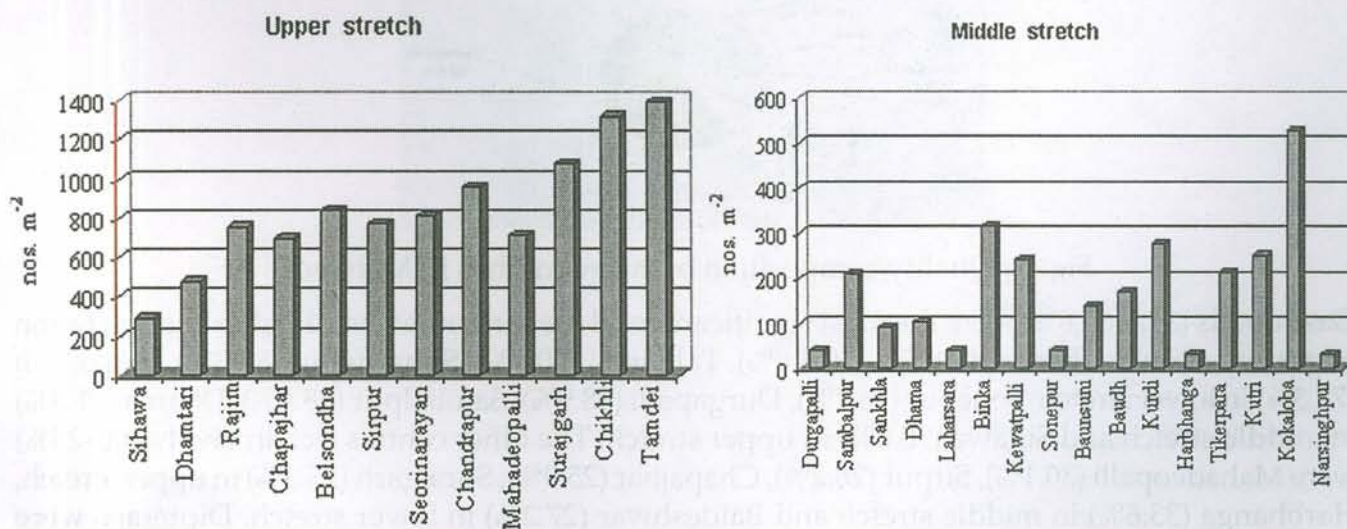
Ostracoda - *Cypris* sp.

Rotifera - *Ascomorpha* sp., *Asplanchna* sp., *Brachionus* sp., *Chromogaster* sp., *Colurella* sp., *Conocheilus* sp., *Diplois* sp., *Filinia* sp., *Gastropus* sp., *Horaella* sp., *Keratella* sp., *Lecane* sp., *Lophocharis* sp., *Monostyla* sp., *Mytilina* sp., *Notholca* sp., *Polyarthra* sp., *Pompholyx* sp., *Rotaria* sp., *Synchaeta* sp., *Testudinella* sp., *Trichocerca* sp.

Protozoa - *Blepharisma* sp., *Bullinularia* sp., *Centropyxix* sp., *Colpoda* sp., *Diffugia* sp., *Euglypha* sp., *Oxytricha* sp., *Spirostomum* sp., *Trinema* sp.

Macrobenthos

Macrobenthos of the Mahanadi system in upper, middle and lower stretches ranged from 6 to 2217 nos m^{-2} with an overall average 390 nos m^{-2} . While the maximum density was recorded at



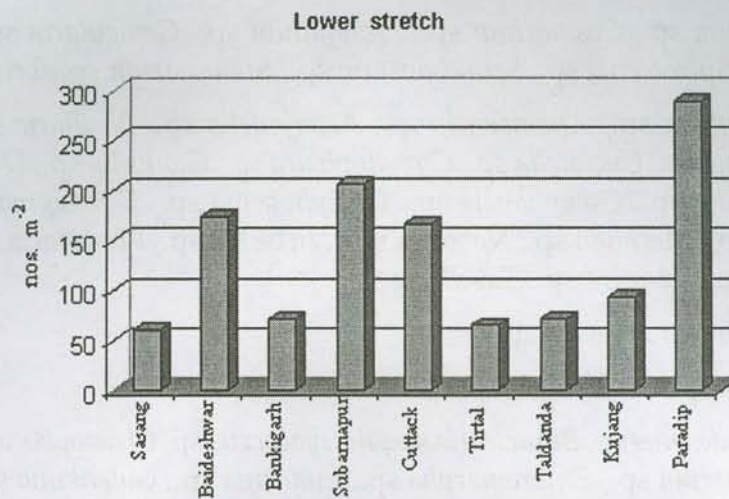


Fig. 4 : Quantitative pattern of macrobenthos in Mahanadi

Tamdei (2217 nos m⁻²) in upper stretch, the minimum was observed at Subarnapur (6 nos m⁻²) in lower stretch. Studies revealed that there was a gradual decline in macrobenthic population from upstream to downstream as well as from post-monsoon to monsoon months.

The zone above Hirakud reservoir had the richest macrobenthos, which drastically declined from a peak of 2217 nos m⁻² to a low value of 28 nos m⁻² at Durgapalli, a site just below the dam (Fig. 4).

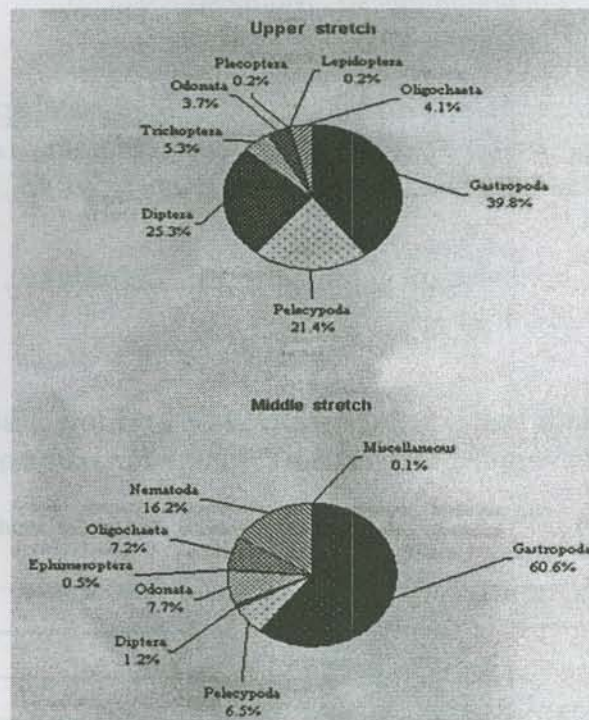


Fig. 5 : Quality composition of macrobenthos in Mahandi

Gastropods (39.8-60.6%) were the most significant in all the three stretches. Higher concentration of gastropods was observed at Tirtal (94.0%), Taldanda (90.2%), Subarnapur (83.3%), Bankigarh (73.3%) in lower stretch, Sonapur (96.7%), Durgapalli (88.9%), Sambalpur (88.6%), Dhama (71.9%) in middle stretch and Sihawa (70.0%) in upper stretch. The other centres rich in bivalves (>25%) were Mahadeopalli (30.1%), Sirpur (28.2%), Chapajhar (25.9%), Surajgarh (25.3%) in upper stretch, Harbhanga (33.6%) in middle stretch and Baideshwar (27.2%) in lower stretch. Dipterans were

important at Chikhli (33.3%), Rajim (32.5%), Surajgarh (30.9%), Tamdei (30.4%), Seorinarayan (30.0%), Chapajhar (29.3%) and Dhamtari (27.2%) in upper stretch only, their occurrence was insignificant in middle and lower stretches. Odonates exhibited significant occurrence at Narsinghpur (33.8%) and nematodes at Kutri (66.3%), Tikerpara (63.3%), Baudh (27.9%) in middle stretch. The other macrobenthic fauna did not show any marked concentration in any of the three stretches. Among annelidian fauna of the macrobenthos, the representatives were solely oligochaetes for the stretch from origin to Taldanda. The sites namely, Sihawa in upper stretch, Durgapalli, Sambalpur and Dhama in middle stretch lacked the representation of any oligochaete or polychaete worm.

Benthic molluscs dominated among the bottom biota of the entire river stretch. It was followed by dipterans in the upper stretch, nematodes in middle stretch and annelid worms in lower stretch of Mahanadi (Fig. 5). The common macrobenthic forms recorded from river Mahanadi are shown below :

Mollusca

Gastropoda - *Amnicola*, *Assiminea*, *Bellamya*, *Campeloma*, *Cerethidea*, *Cyprea*, *Goniobasis*, *Gyraulus*, *Indoplanorbis*, *Littoridina*, *Littorina*, *Lymnaea*, *Melanoides*, *Murex*, *Nassarius*, *Nerita*, *Pila*, *Pleurocera*, *Pugilina*, *Tarebia*, *Telescopium*, *Thiara*, *Tryonia*, *Viviparus*.

Pelecypoda - *Anodonta*, *Corbicula*, *Donax*, *Lamellidens*, *Ligumia*, *Masculium*, *Meretrix*, *Opalina*, *Parreysia*, *Pisidium*, *Siliqua*, *Sphaerium*.

Crustacea

Copepoda - *Cyclops*, *Harpacticus*

Ostracoda - *Cypris*, *Ilyocypris*.

Amphipoda - *Gammarus*.

Cladocera - *Chydorus*.

Decapoda - *Mysis*.

Insecta

Diptera - *Chaoborus*, *Chironomus*, *Culex*, *Culicoides*, *Helius*, *Lumbricillus*, *Probezzia*, *Tabanus*, *Tipula*.

Trichoptera - *Leptocerus*, *Limnephilus*.

Odonata - *Anax*, *Aphylla*, *Argia*, *Cordulegaster*, *Progomphus*.

Plecoptera - *Isogenus*.

Lepidoptera - *Elophila*, *Nymphula*.

Hemiptera - *Corixa*, *Laccotrephes*.

Ephemeroptera - *Caenis*, *Cloeon*.

Coleoptera - *Berosus*, *Eretes*, *Helochaers*.

Neuroptera - *Sialis*.

Annelida

Oligochaeta - *Chaetogastor*, *Lumbriculus*, *Nais*, *Stylaria*, *Tubifex*.

Polychaeta - *Diopatra*, *Nereis*.

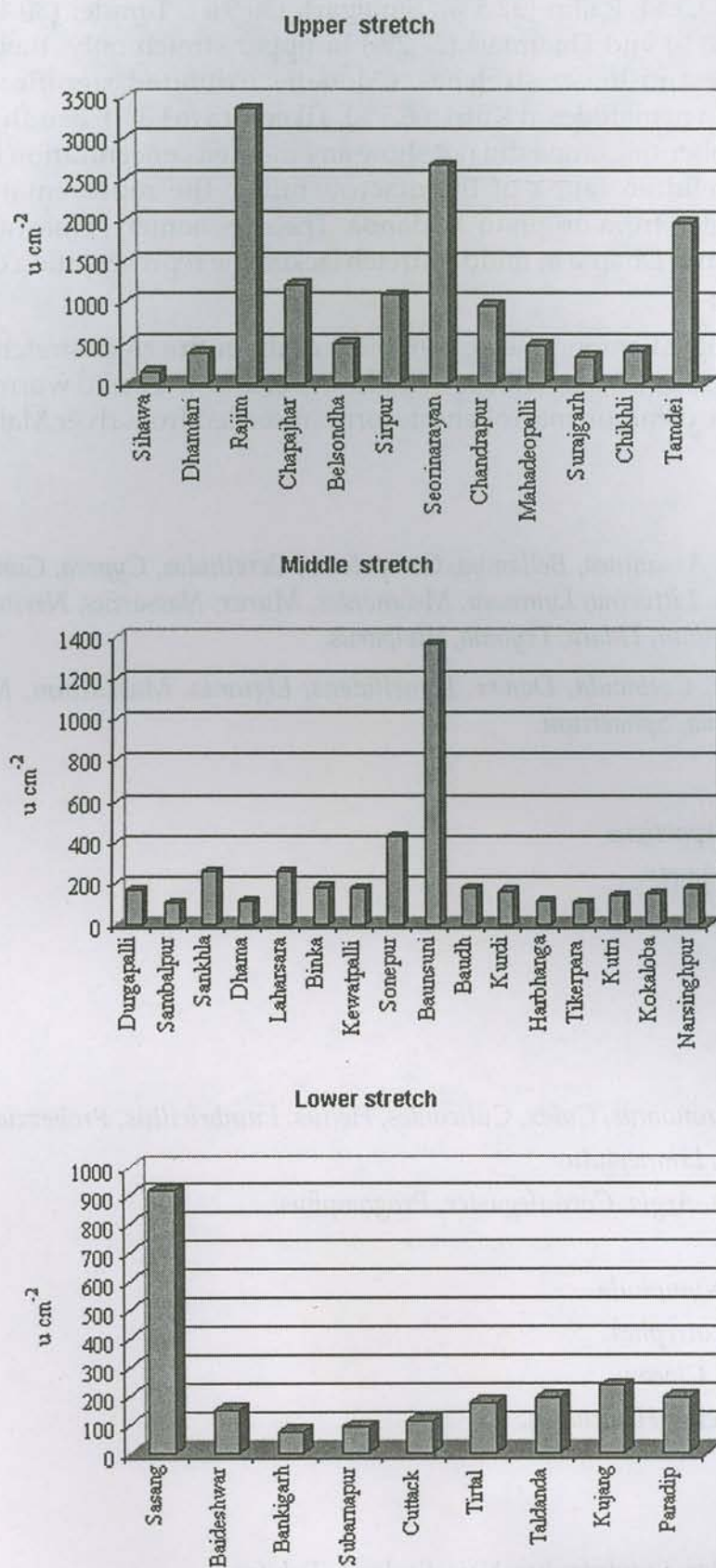


Fig. 6 : Density of periphyton in Mahanadi

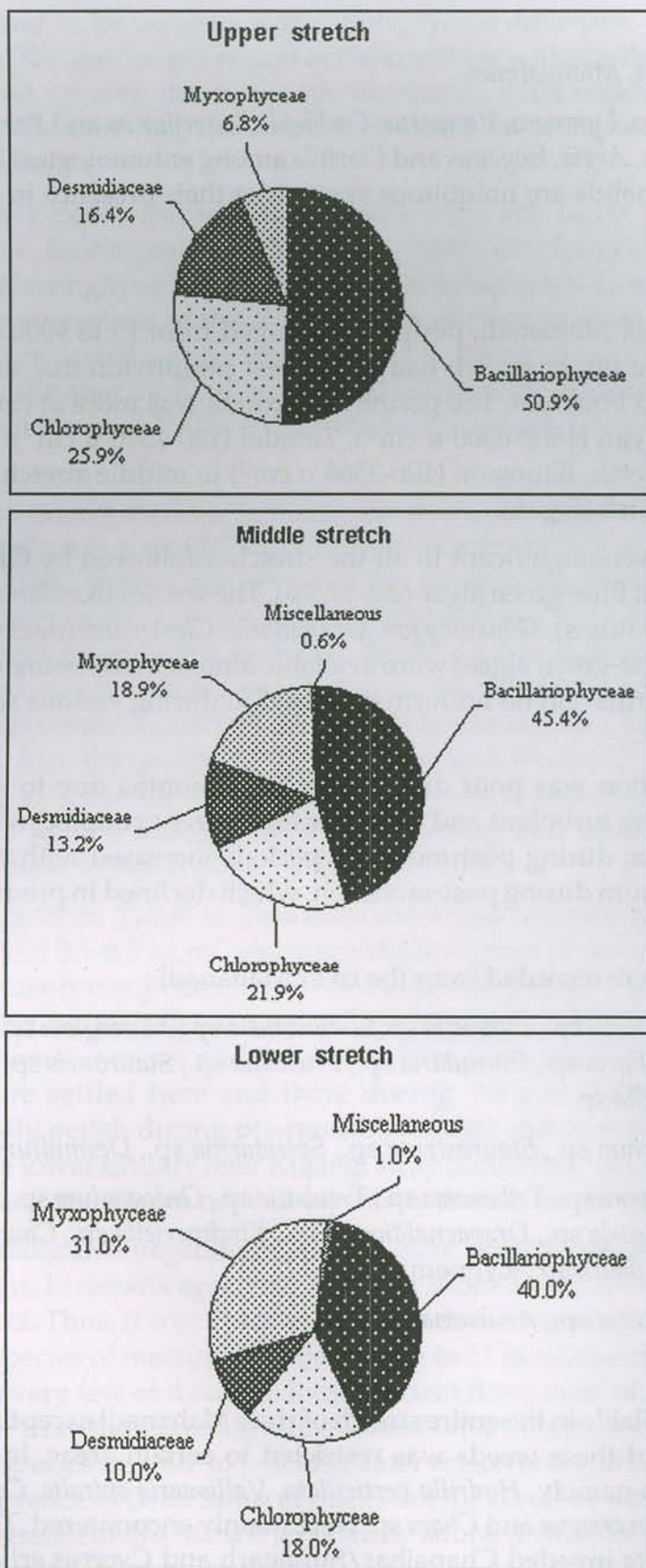


Fig. 7 : Quality composition of periphyton in Mahanadi

Helminthes

Nematoda - *Chromodora*, *Microloaimus*.

The species like *Gyraulus*, *Lymnaea*, *Viviparus*, *Corbicula*, *Lamellidens* and *Parreysia* among molluscs; *Chironomus*, *Limnephilus*, *Argia*, *Isogenus* and *Elophila* among entomological fauna and *Chaetogaster*, *Lumbriculus* among annelids are ubiquitous species for their presence in all the stretches of the Mahanadi river system.

Periphyton

In all the three sectors of Mahanadi, periphyton ranged from 15 to 9000 μcm^{-2} with an overall average 542 μcm^{-2} . The upper stretch had the richest periphyton due to the presence of hard substrata like rocks and boulders. The periphytic growth was more at centres like Rajim (1080-9000 μcm^{-2}), Seorinarayan (1500-6500 μcm^{-2}), Tamdei (120-4590 μcm^{-2}), Chapajhar (1250-2380 μcm^{-2}) in the upper stretch, Baunsuni (106-3366 μcm^{-2}) in middle stretch and Sasang (104-2231 μcm^{-2}) in the lower stretch (Fig. 6).

Diatoms (41.2-69.4%) were significant in all the stretches followed by Green-algae (5.6-38.0%), Desmids (9.7-28.0%) and Blue-green algae (2.2-19.3%). The species like *Navicula*, *Fragilaria*, *Synedra*, *Nitzschia*, *Gyrosigma* (diatoms), *Gonatozygon*, *Genicularia*, *Closterium* (desmids), *Spirogyra* (green-algae) and *Spirulina* (blue-green algae) were available almost in the entire stretch round the year. The other periphytic forms had no uniform distribution during various seasons and at different sampling zones (Fig. 7).

The periphytic deposition was poor during monsoon months due to washing effects of the substrate surfaces by the turbulent and strong water current coupled with high turbidity. The periphytic concentration during post-monsoon periods increased with the advent of summer. The density was maximum during post-monsoon, which declined in pre-monsoon and monsoon months.

The following forms were recorded from the river Mahanadi :

Bacillariophyceae : *Diatoma* sp., *Cymbella* sp., *Asterionella* sp., *Mastogloia* sp., *Meridion* sp., *Amphora* sp., *Rhopalodia* sp., *Tabellaria* sp., *Pinnularia* sp., *Frustulia* sp., *Stauroneis* sp., *Cocconeis* sp., *Melosira* sp., *Diploneis* sp., *Surirella* sp.

Desmidiaceae : *Cosmarium* sp., *Staurostrum* sp., *Spirotaenia* sp., *Desmidium* sp.

Chlorophyceae : *Microspora* sp., *Tribonema* sp., *Treubaria* sp., *Oedogonium* sp., *Protococcus* sp., *Ulothrix* sp., *Uronema* sp., *Binuclearia* sp., *Draparnaldiopsis* sp., *Kirchneriella* sp., *Chaetophora* sp., *Hormidium* sp., *Basicladia* sp., *Cladophora* sp., *Zygnema* sp.

Myxophyceae : *Oscillatoria* sp., *Anabaena* sp.

Macrophytes

Hydrophytes were available in the entire stretch of river Mahanadi excepting in monsoon months when the availability of these weeds was restricted to certain areas. In the upper stretch, six species of hydrophytes namely, *Hydrilla verticillata*, *Vallisneria spiralis*, *Ceratophyllum demersum*, *Najas indica*, *Potamogeton crispus* and *Chara* sp. were mainly encountered. The other aquatic plants like *Marsilea quadrifoliata* invaded Chapajhar/Surajgarh and *Cyperus articulatus* and *Polygonum glabrum* invaded Chandrapur, Mahadeopalli and Surajgarh stretches where some of the above mentioned weeds were also present. During pre-monsoon months Rajim (30.4 kgm^{-2}) was found to be choked with weeds due to low water level and poor flow. The shallow areas of the Hirakud

reservoir were also found to be infested with *Ceratophyllum demersum*, *Najas indica*, *Hydrilla verticillata* and *Chara* sp. The confluence region of the reservoir with the Ib river and Baghra area were found to be choked up with dense aquatic vegetation, even impeding fishing activities. Mura area of the reservoir exhibited fair amount of *Nitella* sp. along with *Spirogyra* sp. at the margins up to 1.5-2.4 m depth.

In the middle stretch, very clear water with fast current, stony and sandy beds did not allow any macrovegetation to grow, leaving aside a few floating forms like *Spirogyra* sp. Thus, the stretch between Hirakud and Narsinghpur had practically no macrophytes. This trend continued even at Sasang and Baideshwar regions of the lower stretch of river Mahanadi. Sasang had scanty representation of *Vallisneria spiralis* and *Crinum defixum* in the crevices of rocky boulders and of *Salvinia molesta* sporadically after the flood season. Baideshwar and its opposite side Gopinathpur exhibited only stray occurrence of *Vallisneria spiralis* at the marginal areas of blind off-shoots of the main river course.

At Bankigarh, *Vallisneria spiralis* showed its settlement along the shallow areas (1.5-2.5 m depth) near the banks. The density was poor ($3-5 \text{ kg m}^{-2}$) due to existence of *Oriza sativa* patches at depth of 0.25- 0.5 m. During flood season, the area receives floating weeds, *Eichhornia crassipes* and *Salvinia molesta* at a density of 20-25 and $5-10 \text{ kg m}^{-2}$ respectively. Subarnapur stretch had thick marginal belt of *Vallisneria spiralis* ($>100 \text{ kg m}^{-2}$) at depth of 1-2 m with patchy representation of *Brachiaria cruciformis* and scanty distribution of *Oriza sativa* almost round the year. Similarly, at Cuttack region, mixed distribution of *Alternanthera sessilis*, *Canna glauca*, *Centella asiatica*, *Cynodon dactylon*, *Ipomoea indica*, *Marsilea quadrifoliata*, *Oryza sativa* and *Vallisneria spiralis* near the banks were also scanty ($2-3 \text{ kg m}^{-2}$). But the abundance of *Eichhornia crassipes* was quite high especially after the monsoon ($5-15 \text{ kg m}^{-2}$) and that to near the barrage and Jobra area. During summer months, the density of these weeds declined to less than 20%.

Upper estuarine stretch from Tirtal to Taldanda exhibited uniform pattern of hydrophyte distribution at a density of $0.1-0.2 \text{ kg m}^{-2}$ along the shallow areas of the bank up to 1.0 m depth. These marginal plants mainly comprised *Brachiaria cruciformis*, *Centella asiatica*, *Colocasia esculenta*, *Coix lacryma-jobi*, *Cynodon dactylon*, *Ipomoea indica*, *Oryza sativa* and *Sagittaria sagittifolia*. After the monsoon run-off, *Eichhornia crassipes* and *Salvinia molesta* are washed down into the stretch at varying density and are settled here and there during the post-monsoon months as stray population, which mostly perish during pre-monsoon season due to exposure and sun drying at the river margins. In the lower estuary near Kujang, stray occurrence of *Oriza sativa* and *Cynodon dactylon* near the marginal areas were noticed especially during monsoon season.

Paradip area barring mangrove vegetations, do not have other types of hydrophytes. Among mangroves of the region, *Excoecaria agallocha*, *Acanthus ilicifolius*, *Phoenix paludosa* etc. are quite common along the banks. Thus, it was observed that the down stretches of the Mahanadi and its distributaries have 34 species of macrophytes belonging to 21 families either as aquatic weeds or marginal plants. While very few of them are local resident flora, most of the species are washed down the river course or from the adjoining nullahs, fields and tributaries during monsoon floods. Thus, even freshwater species migrate to brackishwater region and getting perished during pre-monsoon season. Occurrence of *Oriza sativa* at places are the result of washing from the riparian paddy plots whereas presence of *Brachiaria cruciformis* is natural distribution of the resident species. The details of the plant species are given below :

Nymphaeaceae - *Euryle ferox*, *Nelumbu nucifera*, *N. pentapetala*, *Nymphaea stellata*.

Trapaceae - *Trapa bispinosa*

* **Azollaceae** - *Azolla pinnata*
Potenderiaceae - *Eichhornia crassipes*
Lemnaceae - *Lemna perpusila*, *Wolffia arrihiza*, *Spirodela polyrhiza*
Araceae - *Pistia stratiotes*, *Colocasia esculanta*
Salviniaceae - *Salvinia molesta*
Amaranthaceae - *Alternanthera sessilis*
Scrophulariaceae - *Asteriocantha longifolia*, *Bacopa monnieri*
Gramineae - *Brachiaria cruciformis*, *Coix lacryma jobi*, *Cynodon dactylon*, *Oriza sativa*, *Saccharum spontaerum*
Cannaceae - *Canna glauca*
Umbelliferae - *Centella asiatica*
Amaryllidaceae - *Crinum defixum*
Compositae - *Enhydra fluctuans*
Convolvulaceae - *Ipomea aquatica*, *I. indica*
Onagraceae - *Jussiaea repens*
Marsileaceae - *Marsilea quadrifoliata*
Alismataceae - *Sagittaria sagitifolia*
Typhaceae - *Typha elephantia*
Najadaceae - *Najas indica*
Hydrocharitaceae - *Ottelia alismoides*, *Vallisneria spiralis*

Aquatic Insects

Upstream stretch between Sihawa and Hirakud had prevalence of aquatic insects, especially in the areas with stony river beds. Though in the tow net collection, insect population occurred at a fair number at all the sampling sites during monsoon and post-monsoon months, their density and diversity were different. The following entomological fauna were recorded from the stretch:

Hemiptera - *Nepa* sp., *Ranatra filiformes*, *Notonecta* sp., *Gerris spinolae*, *Plea* sp., *Anisops* sp., *Corixa hieroglyphica*, *Belostoma* sp., *Laccotrephes maculatus*, *Lithocerus indicus*, *Galastocoris bufo*.

Ephimeroptera - *Caenis* sp., *Cloeon* sp.

Odonata - *Aphylla* sp., *Lestes* sp., *Gomphus* sp., *Hagenius* sp., *Anax* sp., *Agria* sp.

Diptera - *Chironomus* sp., *Chaoborus* sp., *Simutium* sp., *Probezzia* sp.

Placoptera - *Isogenus* sp.

Trichoptera - *Hydropsyche* sp.

During pre-monsoon months, *Nepa* sp. and dragonfly populations dominated the sites. Though aquatic insects were available at all the sites during post-monsoon and in the entire stretch barring Sihawa during pre-monsoon months, they were encountered only at four sites namely Dhamtari, Belsondha, Mahadeopalli and Tamdei during monsoon months.

In the middle stretch between Hirakud and Narasinghpur the distribution of aquatic insects among seasons and sites were quite uneven and random. In all seasons, Durgapalli, Kewatpalli, Baudh, Kurdi, Harbhanga, Kutri, Kokaloba and Narsinghpur centres exhibited practically no

insect population due to rapid water current. However, barring the region between Sambalpur and Binka, stretches near Sonepur, Baunsuni and Tikerpara had peak insect populations of 31, 62 and 92 nos m⁻² respectively during monsoon months with a reduction of about 10% in summer months. The insect density during monsoon was higher at Sambalpur–Binka stretch (61-1173 nos m⁻²). Contributions of major insects were around 17.7 % (dragonfly), 13.0% (*Agria* sp.), 12.2% (*Cordulia* sp.), 7.2% (*Hyponuera* sp.), 6.7% (mosquito larvae), 6.6% (Granleas), 5.6% (mosquito), 5.2% (spongilla fly), 5.2% (aquatic spider), 5.2% (*Cynigma* sp), 4.5 % (*Dorocordulia* sp.), 4.4% (*Eualagma* sp.), etc. especially during post-monsoon.

Similar to middle stretch, most of the regions in the downstream exhibited very poor population of insects. The overall densities varied from 124-213, 2-17 and 29-83 nos m⁻² during post-, pre- and monsoon months in the downstream below Sasang.

The following aquatic insects were recorded from the downstream during the studies :

Ephemeroptera - *Caenis* sp.,

Odonata - *Anax* sp., *Agria* sp., *Enallagma* sp., *Urothemis signata*.,

Hemiptera - *Ranatra elongata*, *Notonecta* sp., *Gerris spinolea*, *Plea* sp., *Anisops* sp., *Corixa hieroglyphica*, *Belostoma* sp., *Laccotrephes ruber*, *Lithocerus indicus*.

Coleoptera - *Berosus indicus*.

Trichoptera - *Nymphula* sp.

Diptera - *Culex* sp., *Chironomus* sp., *Probezzia* sp., *Tabanus* sp.

ENERGY TRANSFORMATION THROUGH PRIMARY PRODUCTION

Measurement of rate of conversion of kinetic energy of sun to potential chemical energy of food by chlorophyll bearing organisms gives a dependable parameter to assess the production potential of any aquatic system. The rate of energy transformation by producers, its assimilation and fish production potential in the three stretches of river Mahanadi are presented in Table 14-16.

Table 14 : Energy transformation in river Mahanadi (upper stretch)

Sampling sites	Gross energy fixation rate (Cal m ⁻² d ⁻¹)	Net energy fixation rate (Cal m ⁻² d ⁻¹)	Community respiration (Cal m ⁻² d ⁻¹)	Assimilation energy (%)	Energy lost as respiration (%)
Sihawa	5108	2865	2243	56.1	43.9
Dhamtari	5989	4539	1450	75.8	24.2
Rajim	5418	3412	2006	63.0	37.0
Chapajhar	3735	1994	1741	53.4	46.6
Belsondha	4107	2712	1395	66.0	34.0
Sirpur	3839	2142	1797	55.8	44.2
Seorinarayan	4808	2424	2384	50.4	49.6
Chandrapur	5059	3000	2059	59.3	40.7
Mahadeopalli	3447	1988	1458	57.7	42.3
Surajgarh	5137	2758	2379	53.7	46.3
Chikhli	5000	3339	1661	66.8	33.2
Tamdei	5676	3398	2278	59.9	40.1
Average	4826	2881	1945	59.7	40.3

Table 15 : Energy transformation in river Mahanadi (middle stretch)

Sampling sites	Gross energy fixation rate (Cal m ⁻² d ⁻¹)	Net energy fixation rate (Cal m ⁻² d ⁻¹)	Community respiration (Cal m ⁻² d ⁻¹)	Assimilation energy (%)	Energy lost as respiration (%)
Durgapalli	5321	2970	2351	55.8	44.2
Sambalpur	6267	4482	1784	71.5	28.5
Shankhala	3312	2187	1125	66.0	34.0
Dhama	3083	2224	859	72.1	27.9
Laharsara	2855	1713	1142	60.0	40.0

Sampling sites	Gross energy fixation rate (Cal m ⁻² d ⁻¹)	Net energy fixation rate (Cal m ⁻² d ⁻¹)	Community respiration (Cal m ⁻² d ⁻¹)	Assimilation energy (%)	Energy lost as respiration (%)
Binka	3812	2316	1396	62.4	37.6
Keotpalli	4521	2707	1814	59.9	40.1
Sonepur	3544	2267	1346	62.2	37.8
Baunsuni	2551	1561	990	61.2	38.8
Baudh	3313	2298	1015	69.4	30.6
Kurdi	3090	1839	1251	59.3	40.7
Harbhanga	3066	2082	984	68.0	32.0
Tikerpara	4067	2668	1400	65.6	34.4
Kutri	3470	2580	890	74.4	25.6
Kokaloba	4290	2530	1760	59.0	41.0
Narsinghpur	3289	1966	1325	59.8	40.2
Average	3734	2395	1325	64.2	35.8

Table 16 : Energy transformation in river Mahanadi (lower stretch)

Sampling sites	Gross energy fixation rate (Cal m ⁻² d ⁻¹)	Net energy fixation rate (Cal m ⁻² d ⁻¹)	Community respiration (Cal m ⁻² d ⁻¹)	Assimilation energy (%)	Energy lost as respiration (%)
Sasang	1514	982	532	64.9	35.1
Baideshwar	1964	1250	714	63.6	36.4
Bankigarh	1839	1162	679	63.2	36.8
Subarnapur	1146	736	410	64.2	35.8
Cuttack	1554	1021	539	65.7	34.3
Tirtal	2946	2028	918	68.8	31.2
Taldanda	3437	2160	1277	62.8	37.2
Kujang	5479	3476	2003	63.4	36.6
Paradip	2249	1554	694	69.1	30.9
Average	2459	1597	862	64.9	35.1

In the upper stretch between Sihawa and Tamdei, the rates of gross and net productions (cal m⁻² d⁻¹) ranged between 3447 and 5989 and 1988 & 4539 respectively. The rates were maximum in Dhamtari and minimum in Mahadeopalli with an average of 4826 and 2881cal respectively in the entire stretch. The respiratory loss of energy (cal m⁻² d⁻¹) ranged between 1395 and 2384 (av. 1945). Studies in the stretch reflected that almost 50.4 to 75.8% of the gross energy was actually

stored by them and the rest was lost as heat of respiration. In the middle stretch between Durgapalli and Narsinghpur, the gross energy ($\text{cal m}^{-2} \text{d}^{-1}$) fixed by producers ranged between 2551 and 6267 and net energy between 1561 and 4482. Both the rates were minimum in Baunsuni and maximum at Sambalpur. The high rate of energy fixation may be due to more static condition of the river at Sambalpur with feeble current while the fast current at Baunsuni resulted in decline in the rate. The average gross and net energy ($\text{cal m}^{-2} \text{d}^{-1}$) fixation rates in the entire stretch were 3734 and 2395. Both the rates were comparatively lower in this stretch than the upper stretch. The rates of respiration loss of energy ($\text{cal m}^{-2} \text{d}^{-1}$) ranged between 1125 and 4482 (av. 1325). It has been observed that almost 55.8 to 74.4% (av. 64.2%) of the gross energy fixed by producers was stored by them and the rest was lost as heat of respiration.

In the lower stretch of the river the energy fixation rate was low as compared to other two stretches. The gross and net fixation rate ($\text{cal m}^{-2} \text{d}^{-1}$) ranged from 1146 to 5479 and 736 to 3476 between Sasang and Paradip. Maximum rates were observed at Kujang and minimum in Subarnapur. The average gross and net energy fixation rates ($\text{cal m}^{-2} \text{d}^{-1}$) were 2459 and 1597. Almost 62.8 to 69.1% of the gross energy fixed by producers was stored by them and the rest was lost as respiration.

Productivity of any water body directly depends on the rate with which producers convert light energy into chemical energy, because this is the available energy which flows to higher trophic levels. The average rate ($\text{cal m}^{-2} \text{d}^{-1}$) of gross energy fixation was 3673 and net assimilation of energy was $2291 \text{ cal m}^{-2} \text{d}^{-1}$. The rate of energy in a number of rivers in the country like Ganga, Yamuna, Ghagra, Sone, Brhamaputra etc. were within the range ($\text{cal m}^{-2} \text{d}^{-1}$) of 1752 to 5060. The values observed in the present studies can be well compared with those observed in other rivers. The energy transformation rate observed in many other water bodies like lakes, reservoirs etc. are comparatively much higher than riverine system but the energy converted and stored at the first trophic level is sufficient to sustain the consumers at various levels in the system. The potential energy fixed at primary level depends mainly on producer population besides light energy and nutrient availability. As the producer population in various stretches was comparatively lower and this may be one of the cause for poor energy transformation rate. Apart from the autotrophic source of energy, river also receives large amount of energy from allochthonous sources through the catchment and thus:

$$\text{Total energy available} = \text{Autochthonous source} + \text{Allochthonous source} \\ (\text{energy fixed by producers})$$

As the various stretches of river Mahanadi (especially middle stretch) flows through deep forest, the amount of energy brought from the catchment in the form of organic debris is of high order.

Considerable zonal variations have been observed with respect to rate of energy fixation by producers. The rate was higher in the areas where the river had feeble current, almost stagnant conditions prevailed and it was minimum in the fast current areas. It is thus obvious that even within the same system, the stagnant conditions favoured productivity.

FISH PRODUCTION POTENTIAL OF RIVER MAHANADI

Many workers have used energy flow models to evaluate the fish production potential of aquatic ecosystem. According to second law of thermodynamics, in passing from one trophic level to the other almost 90% of the energy is lost and only 10% of energy is available to the next level. This concept has been applied to calculate the potential energy resource at a particular level in the system. It was observed that in a natural aquatic system having wide spectrum of fishes belonging to various trophic levels, the energy available at fish level may be taken as 1% of gross or 0.5% of

net energy fixed by producers. The fish production potential of river Mahanadi has been estimated by taking 0.5% of net energy fixed by producers as energy available at fish level and the data are presented in Fig. 8.

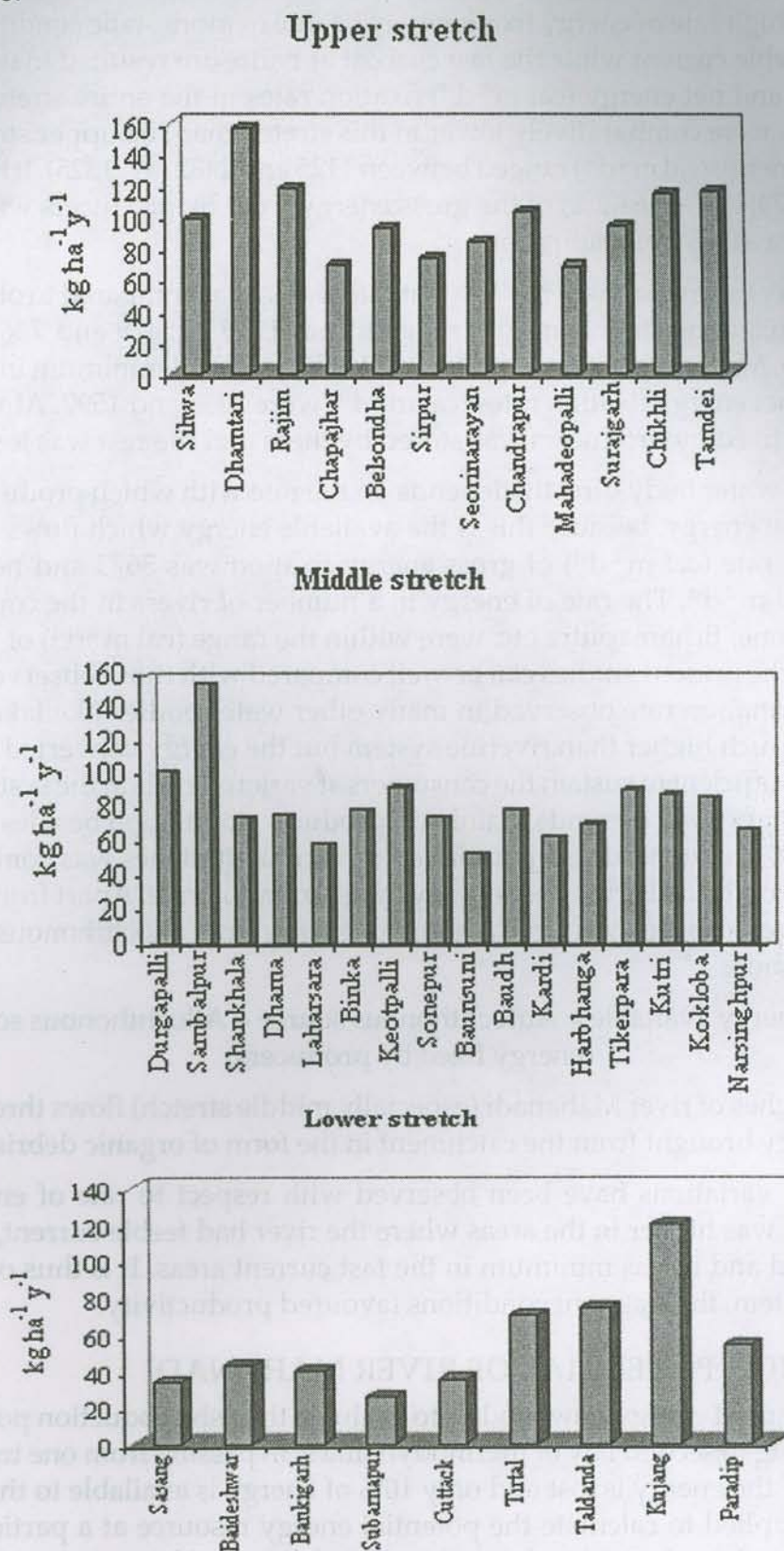


Fig. 8 : Fish production potential of river Mahanadi

In the upper stretch, the fish production potential ($\text{kg ha}^{-1} \text{y}^{-1}$) ranged between 68.8 and 157.1, being maximum at Dhamtari and minimum at Mahadeopalli. The average fish production potential in this stretch was 99.7 kg ha^{-1} . The potential ($\text{kg ha}^{-1} \text{y}^{-1}$) in the middle stretch was in the range 54.0 to 155.2, being maximum at Sambalpur and minimum at Baunsuni. The average production potential in this stretch was $82.9 \text{ kg ha}^{-1} \text{y}^{-1}$, being comparatively lower than the upper stretch. In the lower stretch, the fish production potential ranged between 25.5 and $120.4 \text{ kg ha}^{-1} \text{y}^{-1}$, being minimum at Subarnapur and maximum at Kujang. The average potential in this stretch of the river was $55.3 \text{ kg ha}^{-1} \text{y}^{-1}$, comparatively lower than the other two stretches. The average fish production potential in the entire Mahanadi was estimated at $79.3 \text{ kg ha}^{-1} \text{y}^{-1}$. It has been noticed that the average fish production potential observed in this river is comparatively better than many other rivers of India and as such the river has tremendous fishery potential.

FISH AND FISHERIES

Fish fauna of river Mahanadi excluding its deltaic portion reported by many workers earlier is given below :

<u>Family</u>	<u>Species</u>
Notopteridae	<i>Notopterus chitala</i> , <i>Notopterus notopterus</i>
Clupeidae	<i>Gadusia chapra</i> , <i>Gonialosa manmina</i> , <i>Ilisha motius</i>
Cyprinidae	<i>Catla catla</i> , <i>Cirrhina mrigala</i> , <i>C. reba</i> , <i>Labeo bata</i> , <i>L. callbasu</i> , <i>L. dyocheilus</i> , <i>L. fimbriatus</i> , <i>L. goniuis</i> , <i>L. rohita</i> , <i>L. boga</i> , <i>L. dero</i> , <i>L. boggut</i> , <i>L. ariza</i> , <i>Osteobrama vigorsii</i> , <i>O. cotio</i> , <i>O. cotio cunma</i> , <i>Puntius amphibious</i> , <i>P. gelius</i> , <i>P. sarana</i> , <i>P. sophore</i> , <i>P. ticto</i> , <i>P. chola</i> , <i>P. conchoniuis</i> , <i>P. guganio</i> , <i>P. tetrapagus</i> , <i>P. dorsalis</i> , <i>Tor masal mahanadicus</i> , <i>T. khudree</i> , <i>Laubuca laubuca</i> , <i>Chela bacaila</i> , <i>C. gora</i> , <i>C. untrahi</i> , <i>C. clupoides</i> , <i>C. boopis</i> , <i>Amblypharyngodon mola</i> , <i>Aspidoparia morar</i> , <i>Barilius barila</i> , <i>B. barna</i> , <i>B. bendelisis</i> , <i>B. vagra</i> , <i>Brachydanio rario</i> , <i>Danio devario</i> , <i>D. aequipinnatus</i> , <i>D. crysops</i> , <i>Esomus danrica</i> , <i>Rasbora daniconius</i> , <i>Oreochthys cosuatus</i> , <i>Crossocheilus latius</i> , <i>Garra mullya</i> , <i>G. gotyla</i> .
Balitoridae	<i>Nemacheilus botia</i> , <i>N. botia aureus</i> ,
Cobatidae	<i>Lepidocephalichthys guntea</i> ,
Bagridae	<i>Mystus aor</i> , <i>M. seenghala</i> , <i>M. bleekeri</i> , <i>M. cavasius</i> , <i>M. tengra</i> , <i>M. vittatus</i> , <i>M. gulio</i> , <i>Rita crysea</i> , <i>Batasio tegona</i> .
Siluridae	<i>Ompok bimaculatus</i> , <i>Wallgo attu</i> .
Schilbeidae	<i>Ailia coilia</i> , <i>Clupisoma garua</i> , <i>Eutropiichthys vacha</i> , <i>Silonia silondia</i> , <i>Pseudoeutropius atherinoides</i> , <i>Pangasius pangasius</i> .
Sisoridae	<i>Bagarius bagarius</i> , <i>Gagata gagata</i> , <i>Glyptothorax lonah</i> , <i>Hara hara</i> ,
Claridae	<i>Clarias batrachus</i> .
Heteropneustidae	<i>Heteropneustes fossilis</i>
Belonidae	<i>Xenentodon cancila</i>
Amblycepidae	<i>Amblyceps mangois</i>

Mugilidae	<i>Mugil corsula</i>
Ambassidae	<i>Ambassis nama, A. ranga, A. baculis</i>
Sciaenidae	<i>Johnius dussumieri</i>
Nandidae	<i>Nandus nandus, Badis badis</i>
Gobiidae	<i>Glossogobius giuris, Awaous stamineus</i>
Belontiidae	<i>Colisa fasciata</i>
Channidae	<i>Ophiocephalus gachua, O. punctatus, O. striatus, O. marulius</i>
Mastacembalidae	<i>Mastacembelus armatus, M. punctatus, Macrognathus aculeatus</i>
Anguillidae	<i>Anguilla bengalensis</i>

Fish Fauna of Upper Stretch in River Mahanadi

During present survey, 85 fish species belonging to 23 families were recorded from the upper stretch. These include 68 species out of 102 recorded earlier and 17 new species under 8 families as listed below :

<u>Family</u>	<u>Species</u>
Cyprinidae	<i>Labeo pangusia, Puntius phutunio, Tor tor, Salmostoma phulo, Chela dadidurjori, chela fasciata, Danio malabaricas, Securicula gora</i>
Siluridae	<i>Ompok pabda, Ompok pabo.</i>
Sisoridae	<i>Nagra viridescens.</i>
Aplocheilidae	<i>Aplocheilus panchax</i>
Synbranchidae	<i>Amphipnous cuchia</i>
Sciaenidae	<i>Johnius coitor</i>
Cichlidae	<i>Oreochromis mossambica</i>
Anabantidae	<i>Anabas testudineus, Colisa lalia</i>

Among prawns, *Macrobrachium lamarrei* was available in the stretch above Hirakud. It was reported that before the construction of Hirakud Dam, *M. malcolmsonii* was also available in the Tel river, a tributary of river Mahanadi.

The landing pattern of fish catch based on the survey of local fish market revealed that in upper stretch catfishes (39.9%) were dominant followed by minnows (29.7%), miscellaneous (16.2%) and major carps (14.2%). Among catfishes, *W. attu*, *A. aor*, *A. seenghala*, *E. vacha* and *C. garua* occurred significantly in pre- and post-monsoon seasons. *R. chrysea* was also recorded in pre-monsoon. During monsoon, *A. coila* and *S. silondia* contributed significantly. Minnows comprising *Puntius* spp., *Chela* spp., *Barilius* spp., *Nemacheilus* sp., *Glossogobius* sp., *Gudusia* sp., *Osteobrama* sp. and *Chanda* sp. occurred mainly during post-monsoon whereas, *Danio* sp., *Parluciosoma* sp. and *Eosomus* sp. were important in pre-monsoon months.

Special Features of Landing

The occurrence of *S. silondia* (25%) at Raigarh market with a big specimen (800 mm/5 kg) was quite significant during post-monsoon months. Presence of its young ones in the catch indicates

the breeding of the fish in the river. During pre-monsoon the catch of major carps (40%) was remarkable and the availability of *N. chitala* (180-960 mm/0.1-7.0 kg) at Raigarh is also worth mentioning.

The relative occurrence of minnows was more from Dhamtari to Chandrapur whereas the prevalence of catfishes was comparatively high from Chandrapur downwards, especially during post- and pre-monsoon periods. Monsoon campaign indicated that catches from the upper stretch were lower (22.3%) than the catches from the middle part (77.7%). The peak fishing season is post-monsoon when flood recedes and during summer only deep pools offer ample scope for fishing as the stream becomes extremely shallow. Even during post-monsoon months shallow stretches of the river exhibit insignificant fishing.

In 1975, Chandrapur was established as the best site for spawn prospection when Devarghatta pool near the confluence of Sheonath was also identified as a good collection centre for major carp spawn, which in turn helped improving the major carp fisheries during monsoon. Precious mahseer seed could also be collected at that time from this pool. Occurrence of fingerlings at Chandrapur further confirms breeding of major carps in the upstream.

Tor mosal mahanadicus was recorded from Chandrapur and Devarghatta pools though the yield was negligible. Before Hirakud dam, its fishery was significant but now even in Hirakud reservoir, it is poor.

The miscellaneous group was represented by *L. bata*, *L. fimbriatus*, *C. reba*, *P. sarana*, *Notopterus* sp., *C. batrachus*, *A. testudineus*, *Channa* sp., etc. The greater occurrence of *C. reba* during pre-monsoon at Chandrapur was remarkable.

Interestingly, *C. batrachus* was available in river Mahanadi. Tribal fishermen reported collection of seed of *C. batrachus* near Sihawa during July to November. Juveniles of *C. batrachus* and *A. testudineus* were also available at Dhamtari, Rajim and Mahasamund areas.

It was observed that the main fish markets like Dhamtari, Chandrapur and Raigarh are exclusively governed by the fishermen. The damming of the river has affected the fishery of the stretch. Before construction of Ravishankar Sagar dam, about 20 quintals of fish used to be landed every day at Dhamtari during 1965-70. Contribution of murels was significant followed by major and minor carps. *C. batrachus* and *A. testudineus* were also available in plenty. Likewise, the good catch of *Tor mosal mahanadicus* has also dwindled after the construction of the Hirakud dam.

The catch declines during pre-monsoon months (May-June) as the river stretch between Sihawa and Dudhawa gets completely dried. Afterwards, some water is available near Dhamtari due to discharge from Rudri barrage. The stretch is pretty shallow up to Chandrapur where after the condition improves. On its way to Chandrapur the stretch at Rajim had some water in weed choked condition. The decline in water flow into pools was responsible for the increase in minnows population.

Fish Fauna of the Middle Stretch

In all 30 commercially important fish species under 11 families besides other miscellaneous fishes and priced prawns were recorded from this stretch as listed below :

Cyprinidae	<i>Catla catla</i> , <i>Cirrhinus mrigala</i> , <i>C. reba</i> , <i>Labeo rohita</i> , <i>L. bata</i> , <i>L. calbasu</i> , <i>Cyprinus carpio</i> , <i>Puntius sarana</i> , <i>Tor tor</i> , <i>T. khudree</i> , <i>T. putitora</i> , <i>Chela chela</i> ,
------------	---

Notopteridae	<i>Notopterus notopterus</i> , <i>N. chitala</i>
Siluridae	<i>Wallago attu</i> , <i>Ompok pabo</i> ,
Bagridae	<i>Aorichthys aor</i> , <i>A. seenghala</i> <i>Mystus cavasius</i> , <i>Rita chrysea</i>
Sisoridae	<i>Bagarius bagarius</i>
Schilbeidae	<i>Silonia childreni</i> , <i>Eutropichthys vacha</i> ,
Clupeidae	<i>Gudusia chapra</i> , <i>Ilisha motius</i> (= <i>Pellona</i> sp.)
Engraulidae	<i>Setipinna phasa</i>
Channidae	<i>Channa marulius</i> , <i>C. striatus</i>
Mastacembalidae	<i>Mastacembelus armatus</i>
Mugilidae	<i>Liza parsia</i>
Prawns Palaemonidae	<i>Macrobrachium lamarrei</i> , <i>M. malcolmsonii</i> , <i>M. rosenbergii</i>

In the middle stretch, the fish landing centres like Durgapalli, Sambalpur, Dhama, Binka, Sonapur, Baunsuni, Baudh, Harbhanga, Tikerpara and Narsinghpur contributed 95% of the total catch from the stretch. Post-monsoon period was the peak fishing season (34-250 kg/day/centre; av. 107 kg/day/centre). During pre-monsoon and monsoon seasons, the fishing was impeded and the catch was extremely low (5-40 kg/day/centre; av. 16 kg/day/centre).

Special Feature of Landings

During monsoons only, *Rita chrysea* appeared and dominated the commercial catches (30-75%; av. 38%) from Durgapalli to Harbhanga barring Sambalpur, Binka and Kewatpalli, *Cirrhinus mrigala* (30-35%) and *Labeo rohita* (27-30%) were the main contributors. *C. mrigala* contributed significantly from Dhama to Baudh even during post-monsoon. *Ilisha motius* was available in plenty (40-45%) during monsoon only from Kutri to Narsinghpur.

The occurrence of *Macrobrachium rosenbergii* (8-15%) was observed in the stretch from Sonapur to Narsinghpur during monsoon season. *Macrobrachium malcolmsoni* contributed 20% of the catch of Sonapur during post-monsoon season. The contribution of larger fish declined and that of *Macrobrachium lamarrei* increased gradually during summer months.

Juvenile Fishery of Middle Stretch

Considerable catch of juveniles (10 kg/day) of economically important fishes was recorded in the landings during post-monsoon months in middle stretch. It comprised nearly 40% of desirable species.

Fish Fauna of Lower Stretch

The stretch between Sasang and Cuttack is principally a sector for freshwater fish species. The stretch from Tirtal to Taldanda is located below Cuttack. This upper part of the estuary also possesses many freshwater fish species. Kujang to Paradip is the brackishwater zone of the estuary where marine fishes also enter from the sea.

In the stretch from Sasang to Cuttack, 63 fish species belonging to 21 families were recorded in the survey. The stretch from Tirtal to Taldanda registered 56 species of 27 families and the brackishwater zone had the maximum number of 78 species from 48 families. Thus, in all 197 fish

species were recorded from the lower stretch of river Mahanadi. Besides, the following prawns were recorded from various sectors of the downstream :

<u>Stretch</u>	<u>Prawn species</u>
Sasang to Cuttack	<i>Macrobrachium rosenbergii</i> , <i>M. malcolmsonii</i> , <i>M. dyanum</i> , <i>M. lamarrei</i>
Tirtal to Taldanda	<i>Macrobrachium rosenbergii</i> , <i>M. malcolmsonii</i> , <i>M. rude</i> , <i>Metapenaeus monoceros</i> , <i>M. brevicornis</i> , <i>Leander styliiferus</i> , <i>Penaeus monodon</i>
Kujang to Paradip	<i>Macrobrachium rosenbergii</i> , <i>M. rude</i> , <i>Metapenaeus monoceros</i> , <i>M. brevicornis</i> , <i>Leander styliiferus</i> , <i>Penaeus indicus</i> , <i>P. monodon</i> , <i>P. carinatus</i> , <i>Acetes indicus</i> .

Special Feature of the Landings

A review of the biodiversity pattern of fish species from downstream of Mahanadi reveals that species like *Labeo gonius*, *L. fimbriatus*, *L. bata*, *Tor mosal mahanadicus*, *Barilius barila*, *Brachydanio rario*, *Chela untrahi*, *Notopterus chitala*, *Setipinna phasa*, *Ompok pabo*, *O. pabda*, *Ailia coila*, *Clupisoma garua*, *Silonia silondia*, *Nagra viridescens*, *Bagarius bagarius*, *Rita chrysea*, *Xenentodon cancila*, *Nandus nandus*, *Rhinomugil corsula*, *Mystus cavasius* are distributed mainly in the stretch above Bankigarh. There are other species like *Gudusia chapra*, *Puntius ticto*, *Ostiobrama vigorsii*, *O. cotio cotio*, *Mystus tengra*, *Heteropneustes fossilis*, *Clarias batrachus*, *Pseudoambassis ranga*, *Channa gachua* and *Mastacembelus armatus* also, which exhibits similar exclusive distribution above Bankigarh. In the estuarine sector of the downstream of Mahanadi, Tirtal had some representation of Cyprinids, but at a very low magnitude. Likewise, *Ilisha motius*, *Ophichthus microcephalus*, *Gagata gagata*, *Amphipnous cuchia*, *Odontamblyopus rubicondus*, *Channa punctata*, *C. striatus* and *C. marulius* were mostly available near Cuttack and that to towards Jholasahi and Uttampur. It is not that the catches from the estuary had freshwater fishes from upper reaches and euryhaline species from the lower reaches alone. Quite a good quantity of stenohaline species and marine species from the coastal zones enter the estuary near Paradip and they are caught there. The most common species among them are *Mene maculata*, *Epinephalus diacanthus*, *E. malabaricus*, *Therapon jarbua*, *Caranx gallus*, *C. para*, *Drepane punctata*, *Polydactylus sextaris*, *Polynemus heptadactylus*, *Kurtes indicus*, *Parastromateus niger*, *Pseudorhombus arsius*, *Scoliodon sorrakowah*, *Chilocyllium griseum*, *Rhinobatos obtusus*, *Pseudotriacanthus strigilifer*, *Brachyamblypus brachysoma*, *Sphyræna acutipinnis*, *S. lewini*, *Gerres abbreviata* etc.

Estimated Catch from Lower Stretch

Hardly 10% of the total catch is hawked house to house otherwise the entire bulk of the landings is disposed off through markets and assembly centres (*araths/hats*). The peak disposal (> 46%) of estuarine catches of Mahanadi was during December to February in 1960-64, which declined to 26% in April to August (Shetty *et al.*, 1965). A fluctuation in the hilsha landings in the catch from 13.7 to 309.8 t/y was recorded. It is seen that hilsha and other clupeoids used to cross 50% of the landings at times at certain centres. Likewise, prawn landings also reached sometimes 40% of the total catch as noticed at Baideshwar during pre-monsoon. At other centres also, the pattern of contribution remained same as was in the past barring at Paradip.

During present survey, the information regarding fish catches was gathered from the local fishermen and the fish market. The freshwater stretch yielded approximately about 86.22 t/y whereas the contribution of estuarine stretch was found to be 3674.7 t/y. Besides, more than 500 trawlers fish in the continental shelf near Mahanadi mouth and land coastal fishes at Paradip.

These trawlers operate for about 100 days in a year to fetch about 10 t catch per month per trawler comprising 70% fishes and 30% prawns (including 15% prawn of export quality). Thus, the total landings from the downstream comes to about 20,000 t/y. The landings at Paradip get further complicated as nearly 100 trawlers from Waltair being distressed by cyclonic weather are forced to land their catch 6 to 8 times in a span of two months in a year. Each time, such a trawler makes distressed sell of 20 t of fish (70%) and prawns (30%). In this way, Paradip centre receives an additional catch of 14,000 t/y.

Fishing Crafts, Gears and Fishermen

Information regarding fishing crafts, gears and fishermen were collected from different stretches of river Mahanadi during the survey.

Crafts of upper stretch : Following two types of boats are used for fishing in the Mahanadi

Craft	Local name	Measurements (m)			Other features
		Length	Width	Height	
Boat	Donga	5.0	0.5	0.4	Flat bottomed and dug out type
Boat	Kishti /Naav	6.0-7.0	0.7-1.0	0.5-0.6	Flat bottomed and plank built

Gears of upper stretch : Following 8 types of fishing gears were observed in the upper stretch of river Mahanadi.

Gears	Local name	Measurement and other details	Commonly caught fishes
Long lines	Gadi	10-300 hooks	<i>W. attu</i> , <i>Mystus</i> spp., <i>Mastacembelus</i> sp.
Cast net	Sanki & Barjal	2.5-5.0 m long. Sinkers weight 5-15 g. Operated round the year.	Carps, catfishes, murels, minnows.
Scoopnet	Pelna	Made of 1/143 mosquito net. A sac like net fitted to triangular bamboo frame	Small fishes from shallow waters
Gill net	Fasla	25-50 m long and 3.0 m deep with 20-80 mm mesh bar having master sinker. Made of nylon twine.	Varying types of fishes from deep pools
- Do -	Disco & Fulijal	20-50 m long and 3.0 m deep with 10-50 mm mesh bar having no sinker. Made of monofilament plastic thread.	Different fishes all along the stretch.
Drag net	Jholi & Jholni	30 m long and 1.0 m deep. Small rectangular net made of 1/243 nylon mosquito net, operated by 4-5 persons.	Mainly small fishes and prawns
- Do -	Dholgi	300 m long & 3.5 m deep with 5 mm mesh bar operated by 10-12 persons. Large net made of nylon thread with head & foot ropes.	Mainly catches larger fishes at Chikhli
- Do-	Kadi	Drag-cum-scoop net, made of round meshed mosquito net, 16.5 m long, 0.5 m broad, 1.0 m deep. Net opening with vertical bamboo sticks placed	

Gears	Local name	Measurement and other details	Commonly caught fishes
		0.5 m apart each. Cod end is kept up and during haul mouth of the net is closed	Fry and fingerlings are collected mainly at Surajgarh.
Traps	Dheer, Khandi, Chirahi & Bendwa	Made of bamboo stripes and <i>Jhanau</i> weed	Small fishes and prawns are caught, operated at Belsondha-Sirpur stretch with shallow waters.

Fishermen of upper stretch : Sihawa, Sirpur, Chandrapur and Tamdei were found to be the main fishing centres of the stretch of which 12 core centres possess the following fishing population:

No. of fishermen	No. of fishing families	Structure of fishing population			
		Sex ratio	Adults	Education	Communities
4500	700	1:1	60%	Mostly illiterate	Dheemar, Nishad, Manjhi, Kewat, Mallah

Most of the fisher folk have switched over to other occupations due to non-lucrative fishery failing to generate adequate income. The daily income level of a fisherman is Rs. 10-20/- only on an average.

The details of registered Fisherman Cooperative Societies at the blocks and villages closer to the course of river Mahanadi in the stretch (82 Societies with 3818 members) located at the following centres are given below :

Sl. No.	Centre	No. of Societies	No. of members
Raipur District			
1.	Aurang		15
2.	Mahasamand	19	637
3.	Bilaigarh	4	119
4.	Fingeshwar	5	330
5.	Balodabazar	2	51
6.	Nagri	5	225
7.	Kurud	7	165
8.	Dhamtari	11	625
9.	Kasdol	2	49
Total	70	2888	
Bargarh District			
10.	Tamdei	1	650
Total		1	650

Sl. No	Centre	No. of Societies	No. of members
Bilaspur District			
11.	Chhedolia	1	25
12.	Kogar	1	25
13.	Mulmula	1	25
14.	Sindhul	1	25
15.	Kharod	2	50
16.	Devarghatta	1	12
Total		7	162
Raigarh District			
17.	Padigaon	1	42
18.	Bargaon	1	25
19.	Kaushir	1	23
20.	Mojhapara	1	28
Total		4	118
Grand total		82	3818

Crafts, Gears and Fishing Folks of Hirakud Region

The fishing rights vest with the State Fisheries Department since 1960. Dividing the reservoir into 6 sectors, 5 were leased out for fishing to Fishermen Cooperative Societies @ Rs. 39/km². The sixth sector near dam was kept reserved for security purpose. Experimental and licensed non-commercial fishing only was permitted there. More than 94% of around 3000 fishermen scattered over 120 peripheral villages have fisheries as their major means of sustenance. The important gears are three types of gill nets operated at 3-10 m depth, 4-5 types of drag nets (simple to big) operated in silted areas and hooks and lines operated round the year. Gears with 12.5-203.2 mm meshes are operated in spite of regulation prohibiting the use of gill nets with < 101.6 mm mesh size.

Crafts, Gears and Fishers of Middle Stretch

Plank built canoes called Dongas (3.0-4.5 m long, 0.6-0.75 m wide and 0.4-0.6 m deep) capable of carrying 2-3 fishermen each were found to operate all along the middle stretch of the river Mahanadi between Hirakud and Narsinghpur. Gill net fishing was common throughout the stretch. Cast net and scoop net/deep net were restricted to Kutri, Kokaloba and Narsinghpur centre, while usage of hooks and lines was common all over excepting at Binka and Baudh. Light fishing in the night was found to be very common at all the centres. Operation of traps was usual practice of fishing at Sonapur. The traps are of 4 types as follows:

1. Split bamboo basket type, truncated-cone shaped with double trap doors, 1.5 m long
2. Split bamboo basket type, cylindrical in shape with single trap door, 1.5 m long
3. Split bamboo basket type, cylindrical in shape with double trap doors, 1.0 m long
4. Split bamboo basket type, rhomboid shaped with triangular ends and three faced, 2.0 m long body having three lateral trap doors

Studies on the fishing communities revealed that 41-50 year group was active fishing population contributing maximum (40.38%) followed by 51-60 year group (16.49%), 61-70 year group (12.67%) and 71-80 year group (9.01%). Among the fishing community, 54.16% were real fishermen, 30.16% scheduled caste and 18.4% other classes. Muslims were not involved in the fishing. As much as 48.5, 38.6, 20.7 and 13.0% of them were primary pass, illiterates, middle standard pass and high school level pass respectively. Joint families with 4-7 members, 8-11 members and 12-15 members were 63.00, 30.33 and 6.67% respectively. Nuclear families were more (89.3%) within the community, which exhibited almost 1:1 sex ratio. Among the members of the community, 69.83% were involved in capture fishery and spawn collection, 11.5% in aquaculture, 11.0% in fish processing, 5.5% in other trades and so on. Many fishermen were working as hired labourers during their leisures. None of them had houses, but 83.31% of them possessed boats and gears.

Crafts, Gears and Fishing Folks of Down Stretch

Mostly plank built flat bottomed canoes called Dongas were in use for fishing in the stretches between Sasang and Cuttack. The dimensions of these Dongas varied a lot (3-7 m long, 0.5-1.5 m wide and 0.6-1.3 m high). Besides these Dongas or Dingis, country boats (3.0-4.5 m long, 1.0-1.5 m wide and 0.8-1.0 m high) were recorded as fishing boats at Kujang and Paradip. Paradip had larger mechanized boats.

More than 80% of the large country boats (5-7 m long, 2-3 m wide and 1.0-1.3 m high) at Paradip were converted to mechanized boats. Again at Paradip, there were specially built gill netting boats, wooden trawlers etc. besides trawling vessels and mechanized fiberglass catamarans for coastal fishing. During winter migratory bag net fishing, 2000 more country boats take part in the fishing and for this purpose nearly 6000 migratory fishing folk participate with about 2000 bag nets. Coastal fishing at Paradip is very popular and as such mechanized boats, wooden trawlers, trawling vessels and fiberglass power driven catamarans were operated from two distinct units namely, Sandhakul and Nuabazar bases. Only Sandhakul base had catamarans at the Port area. The details of manpower with their crafts and gears at these two bases are given below :

Coastal fishing base	Total no. of fishing folk	No. of active fishing folk	Other details of active fishing folk
Sandhakul	4485	1398	274 had own boats and own nets 51 had hired boats and own nets 365 had hired boats and hired nets 593 fishing labourers 115 fish marketing women
Nuabazar (Operate wooden trawlers only)	609	207	53 had own boats and own nets 34 had hired boats and hired nets 79 fishing labourers 41 fish marketing women

Through coastal fishing, 70% fishes (mostly estuarine fishes), 15% exportable prawns and 15% other shrimps were landed at Paradip.

Fishing Gears Operated in the Down Stretch

Mainly 17 types of fishing gears were found in operation at the downstream of river Mahanadi. These gears could be grouped under 8 heads according to their mode of operation. Of course, at

Paradip area, many gears were modified and added to the fishing activities, increasing the total types of gear varieties to 48 kinds. During the sample collection and survey of the stretch, local inventories were carried out to ascertain the varieties and the number of fishing gears possessed by the local fishermen.

In the stretch between Sasang and Cuttack, the widely used fishing nets were cast net (*Bhamar jal*), seine nets like purse seine (*Ghai jal*) and large seine (*Ber*), small drift net (*Tong* and *Tona jal*), deep gill nets (*Chandi jal*), set barrier like *Pata jal*/*Gora jal*/*Masari jal* and *Salua* (split bamboo mat).

In the upper estuary between Tirtal and Taldanda, the main fishing nets were cast net, bag net (*Binthi jal*), drag net (*Jalei*), gill nets (*Bhasa jal*) and seine (Purse seine-*Ghai jal*).

In the lower estuary between Kujang and Paradip the fishing nets were cast nets, deep gill nets (*Chandi jal*), seine nets (*Ghai jal*), bag nets, drag net, small drift net (*Chara jal*), split bamboo mat, large seine (*Ber*) and boat seine (*Torania*).

Fishing Folk of the Downstream

Most of the fishers from the stretch between Narsinghpur and sea-mouth had alternative occupations other than fisheries also. They remained occasionally engaged themselves in agricultural activities, worked as casual labourer, cattle maintenance and weaving activities. The family size of active fishers including their family members are enlisted below :

Sampling sites	No. of fishers families	No. of active fishers
Sector 1.	<u>Freshwater stretch between Sasang and Cuttack</u>	
	Sasang	20 70
	Baideshwar	100 300
	Bankigarh	15 50
	Subarnapur	150 400
	Cuttack	
	i) Chowduar	12 60
	ii) Jobra	15 60
	iii) Jholassahi	40 200
Sector 2.	<u>Upper estuarine stretch</u>	
	Tirtal	3 8
	Taldanda	2 3
Sector 3.	<u>Lower estuarine stretch</u>	
	Kujang	7 25
	Paradip	
	a) Ramnagar area	53 250
	b) Paradip proper	
	i) Multi gear operator	607 3000
	ii) Gill netters	- 20,000
	iii) Seasonal bag net users	- 6,000

Downstream of Mahanadi had five Cooperative Societies for the riparian fishermen. The Societies rendered financial help to the fishing member to purchase and maintain their boats, gears and other fishing tools. In lieu of this the catch was marketed under the control of Societies. The salient features of these Societies are as follows:

1. *Ma Bansali Karnadhara Samiti* – The Fishermen Cooperative Society was located at Anulipatna, 3 km downstream of Taldanda in the upper estuary. The Society had 30 members having 10 boats, 30 bag nets (Binthi jal), 30 surface gill nets (Bhasa jal) and 10 deep gill nets (Chandi jal).
2. *Kalinga Karnadhara Samabaye Samiti* – This Society was located at Nuabazar area of Paradip. It had nearly 609 members from Paradip and Ramnagar areas who operated wooden trawlers mainly.
3. *Anusupa Primary Cooperative Fisheries Society* – The Society was located at Subarnapur. It had 1000 members of which 400 were active fishermen. These fishers used to fish in the main river as well as in Anusupa Lake under the administrative control of the Society.
4. *Chowduar Primary Fishermen Cooperative Society* – The Society was located at Chowduar with the fishers of the Cuttack anicut near Chowduar. Presently, it had about 60 member who used to bring their catches to Cuttack market near barrage.
5. *Bansali Primary Fishermen Cooperative Society* – The Society was located at Uttampur, on the opposite bank of Cuttack. It had nearly 200 members who disposed their catch at Jholassahi market in Cuttack.

EXECUTIVE SUMMARY

Ecological status and production dynamics of river Mahanadi was studied from origin to sea mouth.

The average depth of the river ranged from 2.0 to 5.0 m and current velocity 0.51 to 1.613 km h⁻¹. Both depth and current velocity were comparatively higher in the middle stretch.

Sediment from the entire system was dominated by sand (85.8 to 97.5%) having poor to moderate organic carbon, poor available nutrients and near neutral to alkaline pH.

Water was rich in oxygen and moderately high in respect of alkalinity, conductance, dissolved solids, calcium and hardness with distinctly alkaline pH. Although dissolved organic matter was high, the nutrient status, both in respect of nitrate and phosphate was poor in the entire stretch.

Water quality parameters like temperature, pH, dissolved oxygen, carbonate and bicarbonate showed considerable diurnal variations in all the stretches, the intensity being more where the water was stagnant. The diurnal variations in water quality got reflected in the distribution of plankton.

Plankton population did not show any marked variation in the entire river stretch. The overall plankton abundance fluctuated between 106-133 ul⁻¹. Phytoplankton (59.9%) remained dominant component throughout the stretch barring a few exceptions. In all 244 planktonic forms were recorded of which 93 in upper, 57 in middle and 94 in lower stretches.

Macrobenthos decreased from upper stretch (840 nos m⁻²) to lower stretch (135 nos m⁻²). Gastropods (40-61%) and bivalves (6-21%) were important in the entire river stretch. Zonal variation in other benthic group was noticed with prevalence of dipterans in upper stretch, nematodes in middle and annelid worms in lower stretch of the river.

The upper stretch exhibited comparatively rich epiphytes due to its hard substrate with rocks and boulders. This stretch had greater occurrence of aquatic insects also especially in the stony regions.

The clear water, fast current, stony and sandy beds did not allow the macrovegetation to grow in the entire river system. Some aquatic weeds were recorded in the upper stretch.

312 fish species were recorded, of which 85 from upper, 30 from middle and 197 from lower stretches. Catfishes were dominant followed by minnows, miscellaneous and major carps in upper stretch. In middle stretch, catfishes and carps were equally important. Freshwater sector and upper part of the estuary below Cuttack in downstream had freshwater fish species. Marine fishes also usually enter from the sea in brackish water zone of the estuary.

The rate of gross and net energy ($\text{cal m}^{-2} \text{d}^{-1}$) transformation by producers was on an average 4826 and 2881 in the upper, 3734 and 2395 in the middle and 2459 and 1597 in the lower stretches with an overall average of 3673 and 2291 in the entire system.

The average fish production potential ($\text{kg ha}^{-1} \text{y}^{-1}$) was 99.7 in the upper stretch, 82.9 in the middle and 55.3 in the lower stretch. The overall fish production potential in the entire river system was $79.3 \text{ kg ha}^{-1} \text{y}^{-1}$, which was comparatively higher than many other river systems in the country.



Mahanadi Originates at Sihawa in Dist. Raipur



Exposed river-bed of Mahanadi during summer



Rudri canal in upper stretch of Mahanadi



Water holding above the barrage



Ruver shrinking below the barrage



Monsoon view of river Mahanadi



Catfish catch



Mahseer catch



Silonia silondia from upper stretch of Mahanadi



Hybrid carp in river Mahanadi



Retail selling of river catches by fisher women in local market



Gill net (Tengri)



Stake net (Kathijal)



Scoop net (Pelna)



Scoop net (Pelna)



Fish traps (Bendwa)



Ecological sampling work in Mahanadi



Spawn collection through shooting net



Socio-economics of Mahanadi Stakeholders