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Plankton Diversity and Abundance River Mahanadi At Cuttack

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Abstract

Diversity and abundance of various phyto- and zooplanktons were studied at three different sites M1, M2and M3 in the river Mahanadi at Cuttack in 2019 and 2020. Among Phytoplanktons 23 species of Chlorophyceae, 8 species of Cyanophyceae and 11 species of Bacillariophyceae were identified from three sampling sites. On the other hand among Zooplanktons, 11 species of protozoa 10 speceis of rotifer, 7 species of cladocera and four species of Copepod have been identified. Standing stock (n/p) and percentage composition of both phytoplanktons and zooplanktons show a great deal of variations in different seasons in the river system.

Key words : Chlorophyceae, Cyanophyceae, bacillariophyceae, cladocera, copepod, rotifer.

Introduction

The word plankton refers microscopic aquatic floating organisms which offers little or no resistance to the water current and are free floating and suspended in waters. Planktons are grouped according to their size, nature and niche etc. The community consists of animals as large as jelly fish to microscopic organisms. Planktons are to two types: planktonic plants called as phytoplanktons and animals as zoo-planktons. Phytoplanktons are microscopic algae or bacteria and are found as unicellular, colonial or filamentous forms, which carry out photo-synthesis and are grazed upon by zooplanktons and other aquatic organism. The phytoplanktons are a group of heterogeneous microscopic free swimming animalcule components of an aquatic ecosystem. These are primary consumers of phytoplanktons and serve as the main food source for the fish.

According to (Mathew, 1977; Verma and Dutta Munshi, 1987) zooplanktons can be used as indicators of the tropic phase of a water body, they play an important role in transferring to the consumers and hence they occupy the next higher tropic level in the energy flow after phytoplanktons. Planktons form a wide range of morphological and physiological types and are present in vast number of different environments, they have immense potential to form colonies in spite of the high rate of the growth of many organizations, individuals, ecosystems have characteristic communities. According to Odum (1971) biotic community can be defined as an assemblage of population in a prescribed area of physical habitat. It is also defined as the association of organisms to live together to their preferences for certain qualities of physical environments. According to Kerbs (1978) environment has all the selective factors for shaping the evolution organism and hence ecology and evolution are two view points of the same reality. Thus, a biotic community is an association of different organisms living together in a given environmental space and their association may include the representative of all tropic levels. The accumulation of species is a chance factor and their association is permanent for that particular habitat.

Major communities are large size and complete in organization and they are relatively independent. While minor communities are not independent and rely on neighbouring assemblages.

Ecologist of the past century have studied population dynamic when they wanted to study abundance, such studies had been carried out by various investigators have studies community structure and species diversity of plankton viz. (Brown et al., 1995; Sinha et al., 1995; Gujarathi and Kanhere, 1998; Naganandini and Hosmani, 1998; Herbet et al., 2016; Gianuca et al.,2018). The plankton are also sensitive to environmental factors and can be used as indicators.

The planktons are sensitive to environmental fluctuation due to their short life cycle and hence the abundance and species composition is an indicator of the quality of water mass in which there founds.

They not only influence physicochemical parameter of water such as pH, colour, taste and odour but in reality they are a part of water quality. Das and Sreevastava (1959) have reported that Indian waters have less phytoplankton species compared to the temperate regions but the abundance is more than the temperate waters as plankton community in the tropical water is different and it is rich in variety than the temperate water plankton.

Indian workers have found out that distribution and composition of plankton groups varies considerably from pond to pond, lake to take and river to river. The main factor affects the density and diversity of the two planktons is the pattern of algal distribution. The density and diversity of plankton are controlled by several other physicochemical factors of the water apart from the algal distribution, zooplanktons are controlled by teh several physicochemical factors of water. Hanazato and Yasuno (1985), Bhati and Rana (1987) and Takamura et al. (1989) reported temperature, DO and organic matter are the important factors which control the zooplankton growth.

Sastry et al. (1970) have reported fourteen protozoan species, nineteen crustacean species, nine rotifer species and water mites while working on an upper lake of Bhopal.

Moitra and Mukherjee (1972) recorded three copepods, seven cladocera and three rotifer from a fish pond at Kalyani

Phytoplankton is an integral component of riverine ecosystem and the primary productivity of the system depends on it. It acts as a bioindicator of water pollution its presence and absence mainly depends on the biotic and abiotic factors (Hosmani, 1987; Bhatti and Bhatti, 1988; Singh, 1993).

Certain zooplanktons play an important role in aquatic ecosystem. Their seasonal abundance, population peaks depends on water temperature, DO and nutrients present in the medium (Khatri, 1992; Schmid-Araya and Zuniga, 1992; Bais and Agarwal, 1995; Nautiyal et al., 1996.)

The planktons constitute an integral part of the aquatic food chain culminating in the production office. Knowledge of distribution in time and space of environmental condition which is favourable for its development is the fundamental to be scientific utilization of natural water for fishery exploitation. As the phytoplanktons and zooplanktons are bio-indicators of pollution and forms an integral part of the aquatic food chain and investigation have been made in site M_1, M_2 and M_3 of river Mahanadi for two consecutive years 2019 and 2020 to identity the presence of various planktonic groups (taxonomic identification) and quantitative survey of various phytoplanktons and Zooplanktons.

Objective of the Study

1. To study the diversity of planktos available in Mahanadi river system.
2. To study seasonal changes of plankton availability in Mahanadi river.

State Orissa and its Geography

State Orissa of Indian subcontinent extends from 17^0 49' N to 22^0 34' N latitude and from 81^0 27' E to 87^0 29' E longitude on the eastern coast of India (Figure 1). It is bounded by state, West Bengal in the northeast, the Bay of Bengal in the east, the state Jharkhand in the north, Chhattisgarh in west and Andhra Pradesh in the south. Orissa is a beautiful land enriched with abundant natural resources, beautiful mountains, perennial rivers and waterfalls, rich marine wealth and valuable forest heritage, spreading over an area of 15,57,070 sq. Km.

According to Chatterjee's classification, the climate of entire Orissa is of the tropical savannah type and at least one month in a year Orissa receives less than 6.1 mm. Rainfall. As per Thornthwaite's classification, Orissa falls under the "sub-humid" category implying deficit in winter rain. The south-west and the retreating north-east monsoon effectively control its climate. The average rainfall of the state varies from 4.0 mm to 480.0 mm. and the mean atmospheric temperature varies from 16^0 C to 38^0C at different places.

Geography of Cuttack District

Cuttack district is located between Dhenkanal on its northern side and Khurda on its southern side and is present between 18, 45^0 E- to 19,40^0 W and 85,48^0 N-84,27^0 S. The river Mahanadi bifurcates at 20.28^0 N to 85.52^0 E to river Mahanadi and Kathajodi.

Climatology of Cuttack District

From the climatic condition it is marked that the area is geographically situated in subtropical and sub humid zone. The climate of the area is subtropical monsoon type characterized by oppressive hot summer, biting cold winter an high humid rainy season. Higher percentage of humidity throughout the year and well distributed rainfall during monsoon, in fact modified the topography the local climate in the some extent.
The summer season continues from March to June. The average duration of bright sunshine is 7.85 h per day**.**

Rainy Season: This is a hot and humid and wet season. It starts after first fortnight of June and continues up to October. The south-west monsoon sets in towards the end of June. The rainfall is intensified in the months of July and August during which the sky remains cloudy. For several days at a stretch the sky remains cloudy. The average duration of bright sunshine hours is at the minimum i.e. 3.84 h per day. Due to high humidity, the weather remains stuffy and sweaty.

Winter Season: The winter season is from November to February. In this season during both day and night the temperature begins to drops steadily. December and January become the coldest period of the year. The sky remains clear and the duration of the bright sunshine hours is 8.35 h per day.

River System of Orissa: The major river system of Orissa is Subarnarekha, Budhabalanga, Baitarani, Bhrahmani, Mahanadi and Rushikulya. The river Subarnarekha originates in the highlands of Chotanagpur and falls at the Bay of Bengal flowing through the Balasore district. The Budhabalanga river originates from Similipal area of Mayurbhanj district and joins with Bay of Bengal near Chandipur. The river Baitarani originates from Gonasika Mountains of Keonjhar district and falls at the Bay of Bengal through Dhamara delta. The Brahmani river originates from the highlands of Chotanagpur and joins with Bay of Bengal. The river Mahanadi is one of the major water ways of India and the longest river of Orissa. It originates from the highlands of Chhattisgarh near Sihawa in the extreme south-west of Raipur district and falls at the Bay of Bengal.

River Mahanadi: The river Mahanadi is one of the largest river of India. It is about 860 kms in length, one of the World' largest earthen dam is built over it at Sambalpur. Mahanadi arises from Dhamtari district of Chhattisgarh and falls in the Bay of Bengal. The basin of river Mahanadi is shared by Maharashtra, Jharkhand, Orissa and Chhattisgarh. He area occupied by the basin in each state is Chhattisgarh 75,136 sq.km., Orissa 65,588 sq.km. Jharkhand 635 sq.km. Maharashtra 238 sq. Km

Materials and Methods

Study Sites: This riverine ecosystem comes to the rescue of2/3^{rd} population of the district to benefit by using the water for various purposes i.e. bathing, drinking, agriculture, irrigation, pisciculture etc.
The present investigation is aimed to study the ichthyofaunal survey of the river Mahanadi in district Cuttack. And the study has been carried out in three study sites (i) Naraj (M_1); (ii) Sikharpur (M_2) and (iii) Aytepur (M_3), along a approximately 21 kms. Distance where the river is subjected to maximum human activities of the district. The dimension of its contamination at Cuttack city are the addition of untreated domestic sewages, industrial effluents from the industrial estate of Choudwar and Jagatpur, runoff water from agricultural lands and focal matters etc. The river water is used extensively for fishery purposes, irrigation and other public uses.

The present study was carried out at three fixed sampling stations (M_1), M_2 and M_3) for two consecutive years (January 2019 to December 2020).

Site M_1 (Naraj): It is about 10 kms. Upstream of river Mahanadi from sampling station M2 (Sikharpur), this study site is 5 kms. Away from township and in the upstream direction the public interference is less. The river water always remain enriched with surface runoff from nearby locality, runoff agricultural water and very low rate of sewage contamination from nearby villagers this site is treated as the little contaminated zone of the river (plate 1.a).

Site M_2 (Sikharpur): This sampling station is located at the end of Cuttack city on the banks of river Mahanadi after the Mahanadi Barrage. At this point the maximum fishery activity is observed as the fishery product is in a high demand in the Cuttack city. At this site untreated domestic sewages of Cuttack city is discharged into the river waters in enormous quantities. The water is also enriched with waste from bathing, detergent use by the people for bathing for washing clothes sometimes cattle and buffalos contaminate the water by bathing in it. This site is treated as the contaminated zone as the waste waters of Cuttack city is added into the river. (Plate 1.b).

Site M_3 (Aytepur): This study site is 11 kms. Downstream from site M_2 . People living on its banks are highly dependent on the riverine fishery resources for earning their livelihood. Here the river water is contaminated with industrial effluents from the industrial estates apart from the domestic wastes of the human habitations on its banks. Agricultural runoff water through surface runoff bank site abuses by humans and animals are also a source of pollution. Sometimes cattle and buffalos of the area enjoy bathing specially during the summer season and enrich the water by their faecal matters. The pollution has badly affected the health of the inhabitants and the fishery resources of this area. So it considered as the upper contaminated zone of the river. (plate i.c)

Phytoplankton and Zooplankton Sampling: The planktonwere collected by plankton net of standard bolting silk cloth No. 25 (mesh size 0.03 – 0.04 mm) Rheoplankton were collected from different study stations from 100 litre water sample on use of a plastic bucket of 15 litre capacity. Finally the planktons were collected from the plankton net tube and preserved in 4% formaldehyde solution. The sample was thereafter taken to the laboratory for qualitative and quantitative analysis in a sedge wick Rafter type counting cell (1 ml. capacity) and then the planktons were identified counting as per Allen (1930), Fritsch (1965). After shaking the vial containing the concentrated plankton sample a sub sample of 1 ml. was quickly drawn with the help of a pipette and poured in the plankton counting cell. All organisms encountered were represented in absolute numbers. Three counting's for each sample were made and the data represented in the text were average values of counting's. The planktons were identified species wise and tabulated accordingly.
Calculation : No of planktons/ml =
Where,
1 = length
b = breath
d = depth
For the identification and proper arrangement of fresh water algae zooplankton the following works of the researchers have consulted. (Fristch, 1965; Tilden, 1968; Tonapi 1980)

Results : The results of diversity and distribution of planktons are shown in tables and plates.
Phytoplankton composition of the three study sites M_1 (Naraj), M_2 (Sikharpur) and M_3 (Ayetpur) mainly consisted of Chlorophyceae, Cyanophyceae and Bacillariophyceae.

Diversity :A total 23 species of Chlorophyceae, 8 species of Cyanophyceae and 11 species of Bacillariophyceae were identified from the three study stations (Table 1-7 and plate1).

Chlorophyceae : The major group of phytoplankton Chlorophyceae were represented by 23 species from 11 genera. The population varies from 785 n/l to 9.42 n/l in all the three study stations during 2019 and 2020, highest value was found from M_1 in January 2020 and the minimum value was obtained from M_2 in June 2019.

Cyanophyceae :The phytoplanktonic group Cyanophyceae were represented by 8 species from 5 genera.

The population varies from 320.80 n/l to 15.39 n/l in all the three study stations during 2006 and 2007, highest value was found from M_2 in January 2020 and the minimum value was obtained from M_3 in August 2019.

Bacillariophyceae : The phytoplanktonic group Bacillariophyceae were represented by 11 species from 10 genera.

The population varied from 360.94 n/1 to 19.27 n/l in all the three study stations during 2006 and 2007, highest value was found form M_1 in January 2020 and the minimum value was obtained from M_3 in July 2019.

Zooplankton : During the period of study, zooplankton from the three major groups i.e. Rotifera, Cladocerans and Copepods were identified from the three study stations of, Naraj (M_1), Sikharpur (M_2) and Hayatpur (M_3).

Table1. Phytoplankton Species Identified from the Study Sites Naraj (M_1), Sikharpur (M_2) & Ayetpur (M_3) during the Year 2019 and 2020.

plankton type	2019			2020		
	sampling site			sampling site		
CHLOROPHYCEAE	M1	M2	M3	M1	M2	M3
Euglena viridis Ehrenb	P	A	P	P	P	P
Euglena acns Ehrenb	P	P	A	P	P	A
Euglena spirogyra Ehrenb	P	P	P	P	P	A
Euglena eliganas Ehrenb	A	P	P	P	P	P
Volvox globator (L) Ehrenb	P	P	A	P	A	A
Volvox aureus Klein	A	P	A	P	A	P
Cladophora ephiophila Magnus and Wille	P	A	P	A	A	P
Cladophora callicoma Ag.	P	P	A	A	P	P
Oedogonium Coreatematum Wittr	A	A	P	P	P	P
Desmidium cylindricum Grev.	P	P	A	P	A	A
Zygnema peliosporum Wittr	P	A	A	P	P	A
Zygnema varians Kutz	P	A	A	P	P	P
Zygnema pectinatum Vauch	P	A	A	P	P	A

Spirogyra fluviatilis Holse Var. Africana	P	A	A	P	A	A
Spirogyra varians Kutz	P	P	A	P	P	P
Spirogyra striiformis Kutz	P	A	A	P	A	A
Spirogyra longata Vouch	A	P	P	P	P	P
Cosmarium Sp	P	A	A	P	P	A
Cosmarium reniforme Arch	A	P	A	A	P	P
Cosmarium botrytis Menegh	P	A	A	P	P	A
Closterium lanceolatum Kutz	P	A	P	P	P	P
Closterium parvulum Naig	P	P	A	P	P	A
Closterium venus Kutz	A	A	P	A	P	P
Cyanophyceae						
Oscillatoria borneti Zukal	P	P	P	P	P	P
Oscillatoria amphi granulata Van Goor	P	A	P	P	P	P
Oscillatoria tenuis Ag.	P	P	P	P	P	A
Anabaena Circinalis Rabenh	P	P	P	P	A	P
Anabaena biasolatiana	A	P	P	A	P	A
Synechocystis salansis Skuja	P	A	A	P	A	A
Microcystis aeruginosa Kutz	P	P	P	P	P	P
Nostoc linckia Bornd Flah	A	P	P	P	P	A

BACILLARIOPHYCEAE	M_1	M_2	M_3	M_1	M_2	M_3
Pinnularia viridis Kutz	P	P	P	P	P	P
Pinnularia major Kutz	P	A	P	P	P	P
Pleurosigma spenceri Karston	P	A	A	P	A	P
Navicula cuspidate Kutz	P	P	P	P	P	P

Pleurosigma gigantum Gran.	P	A	P	P	A	P
Gomphonema ventricosum Greg.	A	P	A	P	P	P
Gyrosigma attenuatum Kutz	P	A	A	P	P	A
Navicula laterostrate Hust.	P	A	P	A	P	P
Cyclotella comate Kutz	P	A	P	P	P	A
Melosira granulata ralf	P	P	A	P	A	P
Pinnularia gibba Mayr	P	P	P	P	P	A

Table 2. Standing Stock and Percentage Composition of Phytoplan

Month 2006 M_1	**Total Phytoplankton n/1**	**Chlorophyceae**		**Cyanophyceae**		**Bacillariophyceae**	
		n/1	%	n/1	%	n/1	%
Jan.	1240.71	743.13	59.93	154.8	12.49	319.79	25.79
Feb.	551.18	310.25	56.29	80.00	14.52	160.39	29.11
Mar.	450.81	314.66	69.80	59.13	13.14	80.10	17.80
April	381.98	238.27	62.38	59.05	13.40	90.20	24.20
May	355.43	209.31	58.89	39.40	11.10	110.05	30.00
June	215.86	78.79	36.65	23.86	20.33	92.51	43.03
July	182.98	76.48	41.48	31.88	17.52	74.09	40.71
Aug.	148.98	59.34	40.10	47.81	32.31	42.22	28.53
Sept.	279.59	136.00	49.00	51.33	18.48	90.67	32.50
Oct.	356.94	54.46	50.90	46.35	13.02	127.60	35.00
Nov.	476.68	253.13	53.18	67.87	14.26	155.03	32.57
Dec.	570.62	318.68	55.91	74.67	13.10	173.50	30.44

Table 3. Standing Stock and Percentage Composition of Phytoplanktons at M_2 in 2019

Month 2006 M_2	Total Phytoplankton n/1	Chlorophyceae		Cyanophyceae		Bacillariophyceae	
		n/1	%	n/1	%	n/1	%
Jan.	524.00	147.77	28.20	179.89	34.33	196.50	37.50
Feb.	185.43	46.51	25.14	69.17	37.39	69.25	37.43
Mar.	168.71	33.90	20.18	50.89	30.29	83.21	49.53
April	159.43	23.04	14.49	36.74	23.11	99.21	62.40
May	102.33	12.33	12.09	Absent	.....	89.67	87.91
June	93.48	9.42	10.13	Absent	.....	83.58	89.87
July	82.94	16.14	19.68	Absent	.....	80.32	80.32
Aug.	64.69	16.13	25.21	Absent	.....	47.87	74.79
Sept.	98.36	37.62	38.39	28.72	29.31	31.65	32.30
Oct.	187.38	34.41	18.40	40.17	29.48	112.42	60.12
Nov.	238.40	54.03	22.70	22.16	9.31	161.82	67.99
Dec.	381.98	98.34	25.81	51.36	13.48	231.31	60.71

Table 4. Standing Stock and Percentage Composition of Phytoplanktons at M_3 in 2019

Month 2019 M_3	Total Phytoplankton n/1	Chlorophyceae		Cyanophyceae		Bacillariophyceae	
		n/1	%	n/1	%	n/1	%
Jan.	366.87	118.00	32.24	110.39	36.16	137.62	37.60
Feb.	149.38	57.62	38.67	36.55	24.51	54.83	36.80

Mar.	127.63	46.11	36.31	28.45	22.40	52.44	41.29
April	102.11	31.91	31.28	29.90	29.31	40.19	39.42
May	92.68	27.25	29.62	25.28	27.48	39.47	42.90
June	68.30	24.33	35.78	16.88	23.64	27.59	40.58
July	62.50	22.64	36.51	20.09	32.41	19.27	31.80
Aug.	51.95	15.00	29.41	15.39	30.18	20.61	40.41
Sept.	95.38	31.18	32.82	26.70	28.11	37.12	39.07
Oct.	163.47	59.84	36.71	43.15	26.47	60.02	36.82
Nov.	185.58	55.19	29.83	56.04	30.29	73.78	39.88
Dec.	293.34	106.97	36.51	84.33	27.78	101.64	34.69

Table 5. Standing Stock and Percentage Composition of Phytoplanktons at M_1 in 2020

Month 2020 M_1	Total Phytoplankton n/1	Chlorophyceae		Cyanophyceae		Bacillariophyceae	
		n/1	%	n/1	%	n/1	%
Jan.	1370.5	785	57.30	91.66	13.99	360.94	26.93
Feb.	875.65	483	55.20	140.00	16.00	252.00	28.80
Mar.	665.71	391.04	59.07	99.82	15.24	161.41	25.06
April	492.35	282.41	57.04	73.31	14.90	36.28	27.70
May	456.47	272.23	59.07	61.56	13.50	122.21	26.80
June	325.81	128.54	39.55	77.51	23.85	118.95	36.60
July	215.15	91.44	42.53	41.39	19.25	82.13	38.20
Aug.	186.13	73.80	39.60	66.61	35.81	45.74	24.59

Sept.	369.61	188.19	31.00	75.39	20.43	105.42	28.57
Oct.	485.68	290.46	53.42	71.08	15.52	142.25	31.06
Nov.	643.24	36.57	56.28	111.76	17.30	170.67	26.42
Dec.	897.73	491.74	54.82	135.45	15.10	269.82	30.08

Table 6. Standing Stock and Percentage Composition of Phytoplanktons at M_2 in 2020

Table 7. Standing Stock and Percentage Composition of Phytoplanktons at M_3 in 2020

Month 2020 M_3	Total Phytoplankton n/1	Chlorophyceae		Cyanophyceae		Bacillariophyceae	
		n/1	%	n/1	%	n/1	%
Jan.	346.78	124.21	35.29	102.97	29.76	120.93	34.95
Feb.	237.61	77.05	32.51	50.96	21.50	108.85	45.93
Mar.	177.11	52.76	29.81	36.16	20.43	88.08	49.76
April	158.29	52.92	33.18	41.55	26.30	64.02	40.52
May	143.51	30.96	21.65	34.82	24.55	77.22	54.00
June	127.32	57.95	29.88	27.60	21.74	61.49	48.38
July	102.84	31.62	30.65	30.10	29.51	40.64	39.84
Aug.	83.79	21.09	25.41	25.55	30.78	35.15	43.31
Sept.	178.17	51.30	28.62	50.75	28.51	76.31	42.87
Oct.	238.73	72.48	32.95	60.53	25.43	99.03	41.62
Nov.	318.22	90.63	28.05	99.22	31.20	128.15	40.31
Dec.	403.16	43.75	35.67	119.73	29.71	139.52	34.62

Table 8. Zooplankton Species Identified from the Study Sites Naraj (M_1), Sikharpur (M_2) and Ayetpur (M_3) during the Year 2019 and 2020.

	2019			2020		
Protozoa	M_1	M_2	M_3	M_1	M_2	M_3
Amoeba proteus Muller	P	P	A	P	P	A
Amoeba discoides Schaeffer	P	P	P	P	P	P
Amoeba radiosa Ehrenb	P	P	P	P	P	P
Arcella gibbosa Pennard	P	A	A	P	P	A
Arcella vulgaris Ehrenb	P	A	A	P	A	P
Arcella discoides Ehrenb	P	A	A	P	P	A
Euglypha cristata Leidy	A	P	P	P	P	P
Euglypha tuberculata Dujardin	A	P	P	P	P	P
Euglypha ciliate Ehrenb	P	P	P	P	P	P
Difflugia corona Wallich	P	A	P	P	P	P
Difflugia oblonga Ehrenb	P	P	A	P	A	A
Diffugia accuminata Ehrenb	P	A	P	A	P	A
Paramoecium caudatum Ehrenb	P	P	P	P	P	P
Vorticella campanula Ehrenb	P	A	A	P	P	A

ROTIFERA	M_1	M_2	M_3	M_1	M_2	M_3
Brachionus quadridentatus Hermann	P	A	A	P	P	A
Brachiomnus rubens Ehrenb	P	A	P	P	P	P
Keratella tropica Apstein	P	P	P	P	P	P
Asplanchna priodonta Mastak	P	P	P	P	P	P
Rotaria vulgaris Schrank	A	P	P	P	P	P
Filina longiseta Ehrenb	P	P	A	P	P	P
Monstyla bulla Gosse	P	A	A	A	P	P
Monostyla quadridentata Ehrenb	P	P	A	P	A	A
Notholca accuminata Gosse	A	P	P	P	P	A
Platyias quadricornis Ehrenb	P	P	A	P	P	A

Cladocera						
Daphnia carinath King	P	P	P	P	P	P
Simocephalus vetulus Schoedler	P	A	A	A	P	A
Diaphanosoma exisum Sars	P	P	P	P	P	P
Moina micrura Kutz	P	P	P	P	P	P
Ceriodaphnia rigaudi Richard	P	A	A	P	A	A
Ceriodaphnia reticulate	P	A	A	P	A	A
Bosmina sp.	P	A	P	P	A	A
Copepoda						
Mesocyclops leuckartii Claus	P	P	P	P	P	P
Mesocyclops hyalinus Rhberg	P	P	P	P	P	P
Diaptomus wierzeskii Richard	P	A	A	P	P	A
Heliodiaptomus viduus Gurney	P	P	P	P	P	P

Table 9. Standing Stock and Percentage Composition of Zooplanktons at M_1 in 2019.

Month 2019 M_1	Total Zooplankton	Protozoa		Rotifera		Cladocera		Copepoda	
		n/1	%	n/1	%	n/1	%	n/1	%
Jan.	605.30	51.18	8.46	16.76	5.76	49.44	4.47	89.43	31.30
Feb.	753.80	62.80	8.34	18.67	5.68	44.80	9.23	27.33	56.75
Mar.	425.40	32.51	7.65	93.60	23.78	93.30	23.79	00.00	44.78
April	500.50	19.50	3.89	99.05	9.81	79.65	5.93	01.85	4.37
May	270.30	----	----	50.00	8.52	63.69	23.59	56.30	57.89
June	185.60	----	----	31.48	6.39	92.72	5.98	25.80	60.66
July	194.80	----	----	32.78	6.90	17.03	8.78	44.18	74.32
Aug.	165.50	16.78	0.17	17.57	0.65	19.53	1.84	12.10	67.34
Sept.	295.80	17.58	5.96	48.11	6.31	30.11	0.21	99.18	67.52
Oct.	428.10	20.84	4.87	19.47	4.55	15.13	26.90	72.55	63.68
Nov.	545.60	67.36	2.36	55.47	24.48	28.51	23.58	15.71	39.58
Dec.	598.20	62.96	0.53	11.22	9.68	60.44	26.83	74.84	45.96

Table 10. Standing Stock and Percentage Composition of Zooplanktons at M_2 in 2019.

Month 2019 M_2	Total Zooplankton	Protozoa		Rotifera		Cladocera		Copepoda	
		n/1	%	n/1	%	n/1	%	n/1	%
Jan.	218.20	18.94	8.69	35.92	16.48	48.81	22.39	249.21	52.44
Feb.	158.60	29.51	18.68			43.92	27.80	84.56	53.52
Mar.	123.70	29.52	24.00			31.98	26.00	61.58	50.00
April	98.90			58.34	59.54			39.65	40.46
May	136.70	52.86	38.87	61.85	45.88			20.74	15.25
June	186.70	65.88	35.42	65.10	35.00	25.09	13.49	29.92	16.09
July	95.80	17.90	18.85	29.88	31.46			47.20	49.69
Aug.	127.90	29.21	23.00	29.84	23.50	33.65	26.50	34.29	27.00
Sept.	140.30	31.50	22.00	57.40	41.00	27.76	19.83	23.33	16.67
Oct.	180.75			64.06	35.59	43.16	23.98	78.17	43.42
Nov.	187.10	37.40	20.00	96.17	51.43	43.36	20.98	14.24	7.62
Dec.	238.78	54.40	22.86	38.03	15.98	55.19	23.19	90.36	37.97

Table 11. Standing Stock and Percentage Composition of Zooplanktons at M_3 in 2019.

Month 2019 M_3	Total Zooplankton	Protozoa		Rotifera		Cladocera		Copepoda	
Jan.	195.70	21.16	10.85	17.94	8.97	45.81	23.49	110.55	56.69
Feb.	167.90	20.11	12.04			49.06	29.38	97.81	58.57
Mar.	121.60	32.89	26.84					88.52	73.16
April	160.70	31.09	19.43			19.49	12.18	108.43	67.77
May	149.65	35.70	23.96	2049	13.48	55.95	37.55	37.23	24.98
June	138.89	31.49	22.82	18.53	13.44	34.27	24.85	53.70	38.91
July	114.71	55.91	32.13			59.73	34.33	56.01	33.34
Aug.	118.43	33.20	28.22	22.01	88.65	20.96	17.76	41.69	35.33
Sept.	158.94	15.63	9.89	16.97	10.74	51.18	32.39	74.23	46.98
Oct.	228.34	20.02	8.78	32.51	14.26	67.65	29.67	102.81	45.09

Nov.	248.67	38.09	15.36	50.47	20.35	68.15	27.48	89.73	36.81
Dec.	228.50	24.69	10.83	15.08	6.93	80.05	35.11	102.62	45.01

Table 12. Standing Stock and Percentage Composition of Zooplanktons at M_1 in 2020.

Month 2020 M_1	Total Zooplankton	Protozoa		Rotifera		Cladocera		Copepoda	
Jan.	720.35	75.40	10.48	229.32	31.85	203.83	28.31	211.39	29.36
Feb.	695.90	68.46	9.85	116.69	16.79	147.27	28.19	369.96	52.44
Mar.	578.20	50.81	8.79	126.47	23.88	148.55	25.27	251.26	43.47
April	495.60	23.60	5.38	127.66	35.98	88.80	17.40	204.53	41.32
May	378.65	14.78	3.91	78.81	20.85	73.71	19.50	210.70	55.74
June	265.10	----	----	46.72	17.63	38.66	14.59	174.62	67.78
July	298.40	----	----	47.38	15.90	32.39	10.87	218.23	73.23
Aug.	195.80	18.04	9.25	23.30	11.95	16.65	8.54	137.00	70.26
Sept.	378.00	43.85	11.60	52.20	13.81	46.87	12.40	23.80	62.19
Oct.	467.10	63.05	13.50	78.16	16.95	93.53	20.70	227.20	48.65
Nov.	498.60	78.44	15.75	104.08	20.90	127.49	25.60	78.04	35.75
Dec.	563.20	72.12	12.81	103.42	18.37	161.75	28.73	225.71	40.09

Table 13. Standing Stock and Percentage Composition of Zooplanktons at M_2 in 2020.

Month 2020 M_2	Total Zooplankton	Protozoa		Rotifera		Cladocera		Copepoda	
Jan.	565.40	5.09	.75	61.03	8.50	38.03	4.43	10.86	7.32
Feb.	468.60	9.44	2.70	1.79	3.93	21.21	5.90	45.51	2.46
Mar.	395.80	1.10	8.00			18.50	0.00	05.40	2.00
April	287.30	4.89	5.64	13.39	9.51			28.72	4.85
May	198.75	9.36	9.88	1.44	5.98			07.20	4.14
June	143.20	0.49	1.32	5.90	2.10	3.88	6.70	2.73	9.88
July	158.70	2.37	4.16	9.93	8.94	9.91	8.93	5.97	7.97
Aug.	98.65	8.86	9.40	6.17	6.50	1.36	1.80	1.61	2.46
Sept.	273.90	4.74	0.05	5.52	4.00	1.38	9.81	1.31	6.12

Oct.	353.10			04.31	9.55	8.18	4.98	60.51	3.47
Nov.	427.60	7.89	5.90	68.28	9.41	21.69	8.50	9.13	6.19
Dec.	523.45	29.76	4.81	35.46	5.90	11.29	1.28	43.77	7.49

Table 14. Standing Stock and Percentage Composition of Zooplanktons at M_3 in 2020.

Month 2020 M_3	Total Zooplanktor	Protozoa		Rotifera		Cladocera		Copepoda	
Jan.	343.70	2.12	4.86	0.61	6.34	5.92	9.70	34.11	39.10
Feb.	298.41	6.38	2.31	8.54	6.29	0.08	0.16	52.70	1.24
Mar	216.92	5.81	6.58			4.30	9.77	15.88	3.65
April	139.65	5.45	8.31	4.04	1.68			9.24	9.81
May	185.78	4.45	8.31	4.04	1.68			9.24	9.81
June	9.83	7.71	8.29	7.84	9.00	0.65	1.51	0.29	1.20
July	138.61	1.78	5.78	3.91	0.08	1.48	3.35	7.63	8.79
Aug.	107.91	6.91	5.67	6.66	5.57	4.20	2.62	9.37	6.14
Sept.	218.36	5.94	6.51	6.28	6.00	7.50	7.74	1.42	9.11
Oct.	293.11			3.45	8.48	7.46	9.85	22.09	1.67
Nov.	387.52	0.40	8.19	23.53	1.92	02.56	6.50	8.26	5.39
Dec.	465.37	25.92	7.08	07.74	3.17	7.33	8.78	38.62	9.81

Table 15. The Number of Total Phytoplankton Species Identified and their Percentage Belonging to Various Taxonomic Groups in M_1, M_2 & M_3 during 2019.

Species Group	M_1		M_2		M_3	
	No. of Species	%	No. of Species	%	No. of Species	%
2019						
Chlorophyceae	18	52.94	10	44.60	8	44.48
Cyanophyceae	7	20.58	5	23.80	5	27.80
Bacillariophyceae	9	26.46	6	28.80	4	22.80
Total	34		21		17	

Table 16. The Number of Total Phytoplankton Species Identified and their Percentage Belonging to Various Taxonomic Groups in M_1, M_2 & M_3 during 2020.

Species Group	M_1		M_2		M_3	
	No. of Species	%	No. of Species	%	No. of Species	%
2020						
Chlorophyceae	20	54.00	14	51.80	10	43.50
Cyanophyceae	7	18.90	6	22.20	4	17.50
Bacillariophyceae	10	27.00	7	25.00	9	39.15
Total	37		27		23	

Table 17. The Number of Total Zooplankton Species Identified and their Percentage Belonging to Various Taxonomic Groups in M_1, M_2 & M_3 during 2020.

Species Group	M_1		M_2		M_3	
	No. of Species	%	No. of Species	%	No. of Species	%
2020						
Protozoa	11	0.69	10	50	8	40.00
Rotifera	9	8.17	7	45	6	30.00
Cladocera	6	8.78	4	40	3	15.00
Copepoda	4	2.52	4	40	3	15.00
TOTAL	3232		2323		2023	

Discussion :The major zooplankton population of Naraj (M_1), Sikharpur (M_2) and Ayetpur (M_3) of river Mahanadi consist of Protozoa, Rotifera, Cladocera and Copepoda. A total of 14 species from the taxonomic group Protozoa, were identified, 7 species from the taxonomic group Cladocera, 9 species from the taxonomic group Rotifera and 4 species from the taxonomic group Copepoda were identified.

Protozoa:

The population varies from 75.40 n/l to 14.16 n/l, the highest population was observed at M_1 in January 2020 and minimum was recorded from M_2 in July 2020.

Rotifera: The population varies from 229.32 n/l to 11.41 n/l, the highest population was observed at M_1 in January 2020 and minimum was recorded from M_2 in August 2020.

Cladocera:The population varied from 203.83 n/l to 13.04 n/l, the highest population was observed at M_1 in January 2020 and minimum was recorded from M_3 in June 2020.

Copepoda: The population varied from 427.33 n/l to 20.74 n/l, the highest population was observed at M_1 in February 2019 and minimum was recorded from M_2 in May 2019. Low plankton density during rainy season is also due to heavy influx of rain water which washes down the plankton. The plankton concentration decreases during rainy season but increases rapidly with declined with water current and turbidity in post monsoon period Joshi (1994). According to Trivedi et al. (1993) maximum growth of planktons is observed during spring and summer as high temperature and intense sunlight is conducive for plankton growth.

Phytoplanktons show seasonal variation in composition $n1^{-1}$ with a maximum and minimum amount chlorophyceae, cyanophyceae and bacillariophyceae. During the month March, April, May maximum number of phytoplanktons which is an indicator of good physicochemical condition. (Kant and Anand, 1979

Chlorophyceae: Chlorophyceae constituted highest number and percentage of species in M_1, M_2 and M_3. The chlorophycean population consisted of max 23 species of the total number of phytoplankton species. An upstream M_1 maximum number were observed during January 2020 and minimum during August 2019. The chlorophyceae population varied from 30.96 n/l to 743.13 n/l in M_1 out of the total phytoplanktons, in M_2 it varied from 9.42 n/l to 219.90 n/l and in M_3 the population varied from 15.00 n/l to 124.21 n/l. Lower population of chlorophyceae in downstream can be inferred to lower tolerance of some species towards pollutants. Among the dominant species *Euglena viridis, Volvox goblator, Ulothrix* and *Spirogyra.sp.*

Along with temperature, concentration of DO transparency and other factors that control chlorophyte population and the distribution. Lower DO content of water does not facilitate growth of chlorophyceae. The minimum population during rainy season may be due lower DO content and reduced transparency.

Cyanophyceae:Cyanophyceae constituted 23.86 to 154.80 n/l in M1 28.72 to 320.80 n/l in M2 and in M3 15.39 to 119.73 n/l during 2019 and 2020. The US M1 is rich in Cyanophyta population in comparison to M2 and M3 which are more contaminated.

Bacillariophyceae:The bacillariophyceae showed different dynamic during the period of study the population peaked during February and minimum population was observed during September. Factors the favour the growth of bacillariophyceae are low temperature and bright light.

Zooplanktons:Zooplanktons are free swimming microscopic animalcule and these are primary consumer of phytoplankton. Zooplanktons are main food items of fishes and can be used as indicator of trophic levels operating in water (Gulati, 1983; Chapman et al., 1985;)The Zooplanktons population is much lesser in the river in comparison to phytoplanktons. The distribution periodicity and population peaked has been studied by (Jhingran, 1971; Banik and Dutta, 1991; Batish, 1992; Das et al., 1996). Zooplanktons population was found to be at peaked during January which is considered as reproductive phase (December-April as per Govind, (1969). Population of zooplanktons was found to be rainy season which is considered as retardation phase by Govind (1969). The reasons may be greater water speed and reduce transparency these finding are supported by Nasar (1977). In the present study reproductive phase coincides with the finding of Govind (1969) December to April. And maximum population zooplanktons is observed during this phase. Minimum population of zooplanktons was observed during Govind's retardation phase May-June to September.

Cladocera:The peak population of cladocera was observed during December. The cladocera comprised of six species and their population varied from 203.83 n/l to 16.65 n/l at M_1, the population at M_2 varied from 21.36 n/l to 138.03 n/l and at M_3 the population varied from 13.04 n/l to 102.56 n/l.

The Cladocera and Crustaceans from and important link of fresh water ecosystem. These are primary consumers which directly utilize the primary producers. These forms are usually absence in eutrophic condition. Their peak population was observed during spring or early summer when the air and water temperature are high. There is a decline in population during monsoon period and the possible reason may be higher water current and reduce transparency due to turbidity. Photosynthesis is reduced during monsoon period and this has a direct impact on cladocerans as reduced food supply eliminates these species.

Rotifera:Rotifera is an important zooplankton and constitute a major portion of the total zooplanktons. In the present study zooplankton constitute a major portion and this finding is supported by Krishnamurthy et al. (1954). In river Mahanadi Rotiferans comprise nine species and numerical strength varied from 17.57 n/l to 229.32 n/l in M_1, at M_2 the population varied from 11.41 n/l to 107.74 n/l. Edmoudson (1957) and George (1966) finding Corroborate with the present study.

Numerical values remain high from November to April the present finding agrees with studies of Nasar (1977), Sheshagiri Rao and Khan (1982). Rotifers are considers to be primary consumers and feed on phytoplanktons while some feed on detrital matter Sheshagiri Rao and Khan (1982). Large number of Rotifers indicate eutrophication of water Takamura et al. (1989) while their lower density indicate good water quality Sladeck (1983).
Protozoa:Protozoa population and seasonal abundance has been studied byProtozoa population and seasonal abundance has been studied by (Patra and Nayak, 1982; Hosseti, 1989). The population of Protozoans in M_1 varied from 14.78 n/l to 78.44 n/l the population at M_2 varied from 18.86 n/l to 129.76 n/l, at M_3 the population varied from 5.99 n/l to 125.92 n/l. The population reached peak during December of year 2020. Minimum amount of Protozoans 5.99 n/l was observed during rainy season.. Percentage of Protozoans is lesser and fewer in number of the total zooplankton which support the conclusion of this present investigation.

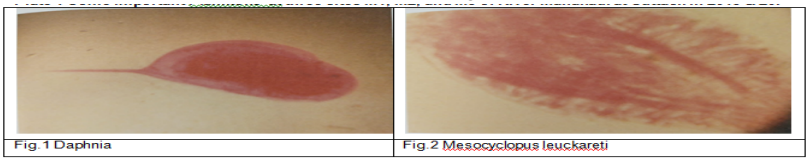
Fig.1 Daphnia | Fig.2 Mesocyclopus leuckareti

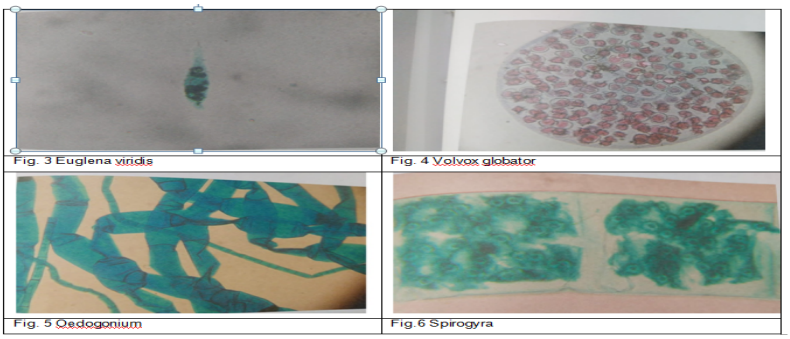
Fig. 3 Euglena viridis | Fig. 4 Volvox globator
Fig. 5 Oedogonium | Fig.6 Spirogyra

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