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Spatio-temporal distribution of zooplankton in Chilka lake- A Ramsar site on the Indian east coast.

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Abstract: The spatio-temporal variation in zooplankton species composition, population density and relative abundance in Chilka lake studied during pre-monsoon (May), monsoon (August) and post-monsoon (October) showed conspicuous fluctuations. The average population density varied between 218 and 1296 org. m^{-3}; while the biomass values ranged from 1.72- 3.30 g m^{-3}. Copepods, chaetognaths, cladocerans, mysids, lucifers, euphausids, siphonophores and sergestids have emerged as dominant groups. Copepods alone contributed nearly 70% of total density. The distribution of zooplankton found to be significantly influenced by salinity variations. Role of other physico-chemical parameters and food supply could also be taken as important factors influencing the sector wise distribution of zooplankton in the lake system.

Keywords: Chilka lake, zooplankton, biomass, abundance

Introduction

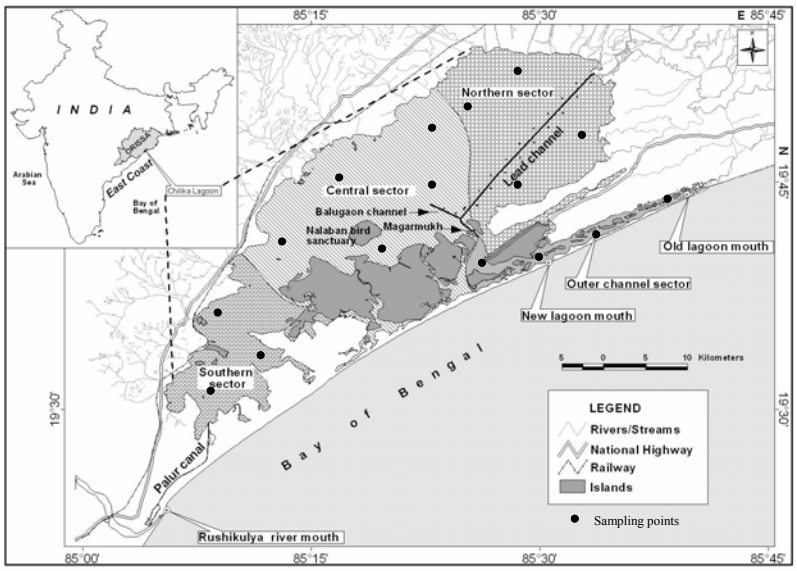
Chilka is the largest brackish water lagoon in Asia and is situated between 19^0 28' - 19^0 54' N and 85^0 06' - 85^0 35' E along the east coast of India. The lagoon has been formed due to sea level changes, advance of riverine delta and formation of barrier spit. The lagoon is connected with the Bay of Bengal through a narrow and constricted outer channel of about 25 km away from its mouth at Satapada. It is fed with fresh water by Daya, Nuna and Bhargavi distributaries of Mahanadi river system and several local streams draining land runoff. As a whole, the lagoon represents a complex habitat where large-scale variation of environmental parameters is seen. In recent years the lagoon ecosystem is suffering from stress due to luxuriant growth of weeds coupled with fall in salinity, siltation besides addition of chemical pollutants of urban and agro-origin. As a consequence of such multidimensional environmental pressure, the biota has experienced visible changes in the community structure of flora and fauna. The contemporary changes took place with respect to zooplankton population is discussed in this paper. Zooplankton, the microscopic and free-swimming animal components of an aquatic ecosystem play an important role in its energy flow process. From the fishery point of view, zooplankton forms the vital links in the pelagic food chain. Many micro zooplanktons also constitute the major food item of the larvae of crustaceans, molluscs and fishes. Thus, abundance of zooplankton practically acts as an ideal index to assess the fertility of a given water mass. The purpose of the present investigation is to obtain information on the hydrographic properties and zooplankton abundance in the lake systems.

Materials and methods

Study area

Chilka lake is the largest brackish water lagoon in Asia. It is a pear shaped water body, which extends from the southeast corner of Puri district to the northeast corner of the Ganjam district. The length of the lake is about 65 km on its axis and its width ranges from 2 to 18 km. The water-spread area of the lake has been estimated at 905 sq. km during summer, which swells to about 1165 sq. km in the rainy season. In recent years, the water spread area has been reduced to about 706 sq. km (Das & Samal, 1998). There are as many as 106 rocky and marshy islands inside the lake. The lake receives fresh water from three main distributaries of Mahanadi namely: Daya Nuna and Bhargavi. In addition some 10 rivulets pore fresh water into it in monsoon seasons. The total fresh water influx into the lake has been

Fig.1. Map showing the sampling points in Chilka lake.



estimated at 3, 75, 000 cusec and contains about 30 million tons of suspended loads (Mohanty, 1988). The lake is shallow having maximum depth of 3.6 m near Kalijai. The rocky island and the outer channel area of the lake basin is predominantly muddy. The lake is connected with the Bay of Bengal by a 35 km long zigzag canal, that open in to the lake at mugermukh. Due to effect of drift current, the opening of the lake into the sea has been altered over the years causing low ingress of seawater into the lake or reverse flow of fresh water from the lake into the sea. The limited water exchange has caused siltation of the lake, which in turn has favoured weed manifestation. Whole of the northern sector and the marginal parts of the central and the southern sectors have also experienced rapid growth of weeds. Anadale and Kemp (1915) made an attempt to study the hydrography and plankton fauna of the lake environment. From hydrographic, fisheries and ecological point of view the lake has been divided into four separate sectors namely: the southern sector, central sector, northern sector and outer channel area. The hydrography, plankton and fisheries of the lake environment have been studied elaborately (Bandopadhyay & Brijgopal, 1991). In order to facilitate free exchange of water between the lake and adjoining sea, the Bay of Bengal, an artificial opening was made in September 2001. This has brought some visible changes in hydrographic and biological characteristic of the lakes. The present investigation is the first zooplankton study since the widening of mouth and thus provides first hand information on the impact of new mouth on the zooplankton community of the lake.

Table1. Sector and season wise abundance of zooplankton in Chilka lake*

Season	Groups	Northern Sector	Central Sector	Southern sector	Outer channel
Pre-monsoon	Copepoda	1240	6440	8700	8300
	Chaetognaths	0	0	130	260
	Sergestids	0	180	70	630
	Mysids	0	0	310	20
	Siphonophores	0	0	130	440
	Cladocerans	140	20	120	40
	Crustacean larvae	90	10	50	450
	Others	270	180	250	230
	Total	**1740**	**6830**	**9760**	**10370**
Monsoon	Copepoda	1540	3600	4710	5230
	Chaetognaths	0	30	1220	1150
	Sergestids	0	240	30	40
	Mysids	0	40	0	630
	Siphonophores	0	0	0	40
	Cladocerans	260	140	0	170
	Crustacean larvae	140	0	30	120
	Others	330	50	130	180
	Total	**2270**	**4100**	**6120**	**7560**
Post-monsoon	Copepoda	4230	5500	6820	4950
	Chaetognaths	240	190	90	460
	Sergestids	60	360	230	330
	Mysids	330	440	0	140
	Siphonophores	0	0	0	340
	Cladocerans	320	250	40	120
	Crustacean larvae	20	80	0	350
	Others	130	90	0	30
	Total	**5330**	**6910**	**7180**	**6720**

*nos. m^{-3}

Sampling and analytical methodologies

A network of 16 sampling stations were established spreading over all the four sectors viz, 3 stations in southern sector, 5 stations in the central sector, 4 stations in the northern sector and 4 stations in the outer channel (Fig.1). The surface zooplankton samples were collected from each sampling station by filtering 1000 liter of surface water by plankton net (mesh size: 40µ). Immediately after the collection, the plankton was preserved in 5% formaldehyde solution. The zooplankton were identified up to their group level by the help of ICES Zooplankton Methodology Manual and the total number is expressed in terms of organisms per cubic meter (nos. m^{-3}) (Lenz, 2000). The biomass of the zooplankton was estimated by volume displacement method and expressed as g m^{-3} (Lenz, 2000; Sameoto *et al.*, 2000).

The surface water collected using a clean plastic bucket was used to study various parameters *viz*. temperature, pH, DO, BOD and salinity. The onboard measurement of pH, water, temperature and fixation for DO measurement were carried out immediately after the collection. DO and BOD were measured using Winkler's method and the BOD was calculated from the difference of DO concentration after 5 days of

incubation at 20°C (APHA, 1998). Salinity analysis was done by Mohr-Kundsen's titrimetric method.

Table 2. Sector and season wise of zooplankton composition in Chilka lake

Season	Groups	Northern Sector	Central Sector	Southern sector	Outer channel
Pre-monsoon	Copepoda	71.26	94.29	89.14	80.04
	Chaetognaths	0.00	0.00	1.33	2.51
	Sergestids	0.00	2.64	0.72	6.08
	Mysids	0.00	0.00	3.18	0.19
	Siphonophores	0.00	0.00	1.33	4.24
	Cladocerans	8.05	0.29	1.23	0.39
	Crustacean larvae	5.17	0.15	0.51	4.34
	Others	15.52	2.64	2.56	2.22
	Total	**100.00**	**100.00**	**100.00**	**100.00**
Monsoon	Copepoda	67.84	87.80	76.96	69.18
	Chaetognaths	0.00	0.73	19.93	15.21
	Sergestids	0.00	5.85	0.49	0.53
	Mysids	0.00	0.98	0.00	8.33
	Siphonophores	0.00	0.00	0.00	0.53
	Cladocerans	11.45	3.41	0.00	2.25
	Crustacean larvae	6.17	0.00	0.49	1.59
	Others	14.54	1.22	2.12	2.38
	Total	**100.00**	**100.00**	**100.00**	**100.00**
Post-monsoon	Copepoda	79.36	79.59	94.99	73.66
	Chaetognaths	4.50	2.75	1.25	6.85
	Sergestids	1.13	5.21	3.20	4.91
	Mysids	6.19	6.37	0.00	2.08
	Siphonophores	0.00	0.00	0.00	5.06
	Cladocerans	6.00	3.62	0.56	1.79
	Crustacean larvae	0.38	1.16	0.00	5.21
	Others	2.44	1.30	0.00	0.45
	Total	**100.00**	**100.00**	**100.00**	**100.00**

*nos. m^{-3}

Results and discussion

The abundance of zooplankton in Chilka lagoon during the sampling period varied between 1740-10370 nos m^{-3} (Table-1). Pre-monsoon registered the highest abundance (1740-10370 nos m^{-3}), with average value (7175 nos m^{-3}) followed by post-monsoon (5330-7180 nos m^{-3}) with average value 6535 nos m^{-3} and monsoon (2270-7560 nos m^{-3}) with average abundance of 5013 nos m^{-3}. Inter sector comparison showed relatively higher abundance in the outer channel area (6720-10370 nos m^{-3}) followed by southern sector (6120-9760 nos m^{-3}), central sector (4100-6910 nos m^{-3}) and northern sector (1740-5330 nos m^{-3}). **Anon (2002a)** also reported the higher zooplankton density during the high salinity phase and during the monsoon season.

The population density of zooplankton showed considerable spatial and temporal variations depending upon the prevailing environmental conditions. The relative abundance of major groups also showed conspicuous seasonal variations (Table 2). Copepods had emerged as the most dominant group throughout the study period. They shared about (67.84- 94.99%) followed by chaetognaths (0- 19.931%), cladocerans (0-11.45%), mysids (0- 8.33%), crustacean larvae (0- 6.17%), sergestids (0- 6.08%), siphonophores (0- 5.06%) and others (0- 15.52%). The copepods had virtually regulated the community size of zooplankton during all the seasons and in all sectors. These population sizes were more in central sector compared to outer channel area, southern sector and northern sector in order (Table 2). Copepods also exhibited seasonal fluctuations in different sectors. Higher copepod population was recorded in the pre-monsoon season. In northern sector the chaetognaths, sergestids and mysids were absent both in the pre-monsoon and monsoon periods. Siphonophores remained absent in the northern sector in all the seasons. The greater abundance of chaetognaths was associated with relatively low temperature and high salinity. Contrary to this, the proliferation of siphonophores was observed to be associated with high temperature and high salinity. Their peak abundance in the outer channel area showed that seawater ingress controls their abundance. Higher abundance of cladocerans during monsoon in outer channel area also indicates its association with salinity. Several authors have also reported earlier that zooplankton population in the lagoon is dominated by the copepods and are controlled by salinity and temperature (Sewell, 1922; Devasundaram & Roy, 1954; Rajan, 1964; Jhingran & Natarajan, 1966; Patnaik, 1986; Sarma *et al*., 1988).

The biomass of the total zooplankton in the lagoon ranged from 0.68-3.94 g m^{-3} during the three seasons. The highest biomass of (3.94 g m^{-3})

was recorded during the monsoon period in the outer channel area that could be due to the higher number of marine species. The lowest value of 0.68 g m^{-3} was recorded in northern sector during the pre-monsoon season. Season-wise average biomass values indicated that highest value was obtained during the pre-monsoon season (3.30 g m^{-3}) followed by post-monsoon (2.23 g m^{-3}) and monsoon (1.72 g m^{-3}) (Table 3).

recorded pH suggested that the lagoon water is alkaline in all seasons. Alkaline nature of the lagoon water was also reported previously by (Panigrahi *et al*., 2007; Mohapatra *et al*., 2007).

Low transparency was recorded in the monsoon season in all the sectors except the southern sector. Addition of silt borne fresh water could be the reason for such turbulent situation. The DO in the lagoon remained always above 5.0

Table 3. Zooplankton biomass in Chilka lake (Sector-wise and season-wise)

Season	Nortern Sector	Central Sector	Southern sector	Outer channel
Pre-monsoon	0.68	4.22	1.98	6.32
Monsoon	0.94	0.98	1.02	3.94
Post-monsoon	1.24	2.12	2.42	3.14

The different environmental variables connected to the seasonal variations are presented in Table 4. The environmental variables clearly marked the seasonal as well as sector wise variations.

The water temperature was low during in the

mg/l, which indicates the healthy state of the lagoon. The free exchange of seawater and lagoon water has probably improved the health of the lagoon system. Salinity in the lagoon exhibited well-marked seasonal and sectoral variations. The salinity remained high during the pre-monsoon

Table 4. Seasonal variation of mean, standard deviation (s.d.), of environmental variables in Chilka lake

Season	Parameters	Northern Sector	Central Sector	Southern sector	Outer channel
Pre-monsoon	Water temp. (^{0}C)	28.12 ± 2.02	28.24 ± 1.74	28.64 ± 1.48	29.32 ± 1.64
	pH	8.48 ± 0.76	8.52 ± 0.45	8.32 ± 0.36	8.18 ± 0.36
	Depth (cm)	62.4 ± 22.8	112.86 ± 29.42	186.5 ± 20.92	198.68 ± 70.62
	Transparency (cm)	34.68 ± 22.68	67.84 ± 28.68	102.45 ± 36.82	72.46 ± 36.54
	Salinity (PSU)	5.46 ± 4.38	15.78 ± 7.42	14.26 ± 4.26	28.42 ± 6.22
	DO (mg/l)	6.12 ± 2.42	6.84 ± 1.18	7.24 ± 0.82	7.64 ± 0.92
	BOD (mg/l)	5.46 ± 3.02	2.24 ± 1.48	1.72 ± 0.92	2.32 ± 1.02
Monsoon	Water temp. (^{0}C)	29.64 ± 1.42	30.12 ± 1.26	30.48 ± 1.22	30.62 ± 1.44
	pH	7.84 ± 0.34	8.14 ± 0.24	8.22 ± 0.16	8.16 ± 0.22
	Depth (cm)	112.46 ± 42.46	156.12 ± 48.28	236.24 ± 43.48	234.04 ± 64.48
	Transparency (cm)	24.98 ± 14.26	58.34 ± 36.12	146.23 ± 51.16	27.86 ± 16.92
	Salinity (PSU)	4.28 ± 3.24	13.42 ± 10.64	18.24 ± 6.32	15.12 ± 13.26
	DO (mg/l)	5.24 ± 2.42	6.64 ± 0.82	7.14 ± 0.68	7.18 ± 0.52
	BOD (mg/l)	4.04 ± 2.03	2.46 ± 1.22	1.94 ± 0.72	2.12 ± 0.86
Post-monsoon	Water temp. (^{0}C)	24.64 ± 3.10	25.48 ± 3.12	26.64 ± 2.64	24.92 ±2.68
	pH	8.16 ± 0.31	8.38 ± 0.42	8.42 ±0.26	8.30 ± 0.22
	Depth (cm)	82.38 ± 32.46	136.14 ± 42.68	224.12 ± 29.28	210.46 ± 64.58
	Transparency (cm)	35.68 ± 19.42	73.18 ± 36.82	128.46 ± 61.24	64.32 ± 33.68
	Salinity (PSU)	1.28 ± 0.56	5.72 ± 3.38	10.02 ±3.16	8.48 ± 7.42
	DO (mg/l)	6.64 ± 2.26	7.86 ± 1.24	7.64 ± 0.74	8.10 ± 0.94
	BOD (mg/l)	3.28±2.42	1.84±0.78	1.76±0.68	1.56±0.62

Table 5. Correlation matrix of zooplankton population with environmental variable in Chilka lake

Zooplanktons	Water ^{0}C	pH	Depth	Transparency	Salinity	DO	BOD
Copepods	0.689	0.712	0.322	0.499	0.782	0.289	-0.188
Chaetognaths	-0.511	-0.239	0.411	-0.118	-0.449	0.239	0.144
sergestids	0.518	0.502	-0.318	0.223	0.543	0.301	0.188
Mysids	0.402	0.318	-0.44	0.318	0.518	0.289	0.139
Siphonophores	0.819	0.718	-0.218	0.501	0.901	0.301	0.111
Cladocerans	-0.689	-0.504	0.813	-0.432	-0.701	0.289	0.133
Crustaceans	0.432	0.518	-0.432	0.318	0.661	0.311	0.328
Others	0.411	0.419	-0.232	0.311	0.501	0.412	0.316

post-monsoon season in all the sectors. The throughout the lagoon, compared to all other

seasons, which is due to the lack of fresh water inputs (Mohapatra *et al*., 2007; Mohapatra, 2008). The northern sector exhibited highest fluctuation of salinity, where as the southern sector exhibited limited range of salinity fluctuations. BOD value in all the sectors, except the northern sector, was < 3.0 mg/l, while in the northern sector it was > 3.0 mg/l. This condition of highest fluctuation in the northern sector was due to the decomposition of weeds as a result of salinity increase during the pre-monsoon as was reported by Mohapatra (2008).

Correlation matrix of environmental variables with the different zooplankton groups was presented in Table 5. The population of copepods, sergestids, mysids, crustacean larvae and siphonophores exhibited good positive correlation with the salinity, water temperature and pH. Cladocerans exhibited good negative correlation with salinity, water temperature and pH indicating their fresh water origin and proliferation.

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