OBSERVATIONS ON THE SEASONAL FLUCTUATIONS OF PLANKTON IN THE CHILKA LAKE

S. PATNAIK

Central Inland Fisheries Research Institute; Sub-station, Cuttack

ABSTRACT

This paper gives an account of the main features of the plankton of the Chilka Lake from April, 1964 to March, 1965. The seasonal fluctuations of the main constituent groups of phytoplankton and zooplankton in relation to some of the environmental variables have been discussed. The diatoms and copepods formed the dominant groups in the plankton during the above period.

INTRODUCTION

The Chilka Lake constitutes an interesting environment for the study of plankton because of the very variable hydrological conditions from place to place and from season to season. The earlier works on the plankton of the lake include those of Sewell (1924) on copepods, Biswas (1932) on algal flora, Devasundaram and Roy (1954) and Roy (1954) on the periodicity of plankton diatoms and Jhingran (1963) on the general plankton. The present investigation was undertaken to study in detail the qualitative and quantitative variations of plankton in different parts of the lake in relation to some of the physico-chemical conditions of water during the period April, 1964 to March, 1965.

The Chilka Lake is a brackishwater lagoon connected with the Bay of Bengal by a channel. The lake has been arbitrarily divided into four sectors as shown in Fig. 1. The northern sector is the largest and also the shallowest, with an average depth of 48 cm in summer and 109 cm during the monsoon period. The inflow from the rivers Daya and Bhargavi renders the water almost fresh during the monsoon period. Salinity showed wide variation between 0.23‰ in September and 20.98‰ in June (Sarkar, MS). The southern sector is comparatively smaller but deeper, varying in depth from 114 cm in summer to 161 cm during the monsoon period. The effect of fresh water from the rivers during monsoon and the inflow of sea water from the channel in summer is comparatively less felt in this sector because of its peculiar geographical position. On account of this, fluctuations in salinity were comparatively less and varied between 5.87‰ in November and 17.14‰ in July. The central sector showed salinity variation from 2.85‰ in October to 23.25‰ in June. The average depth varied between

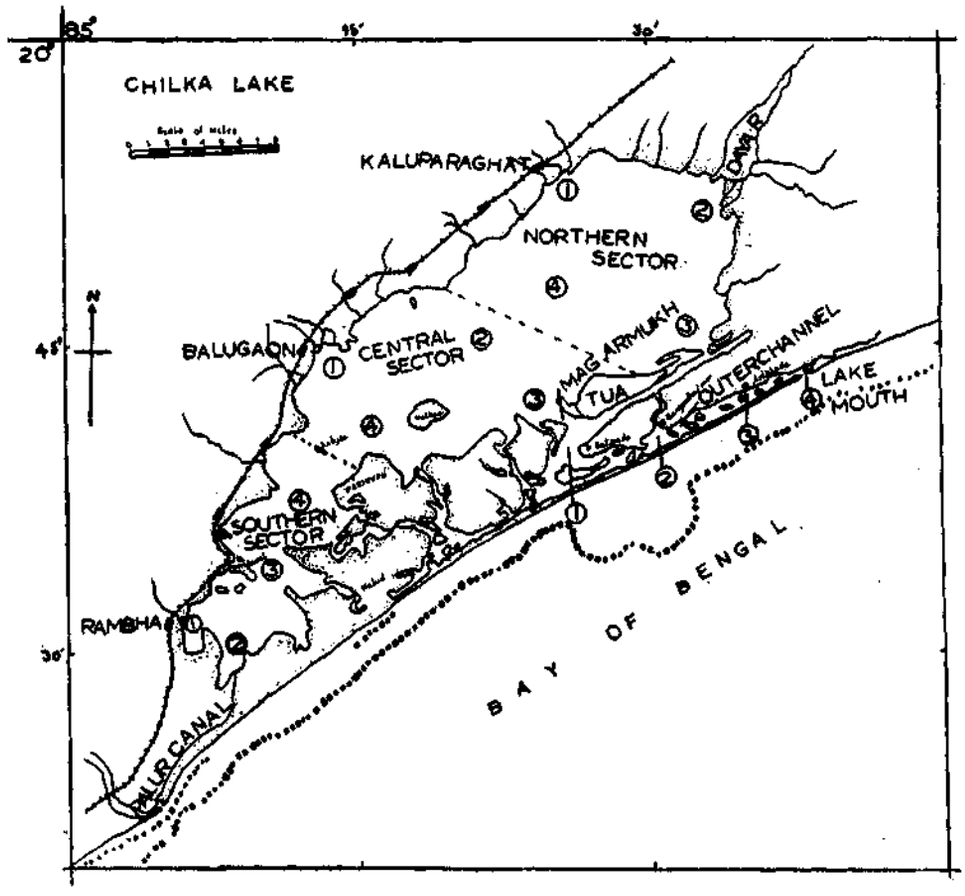

FIG. 1 Map showing the Chilka Lake and the sixteen stations from where samples were collected.

104 cm in summer and 167 cm in monsoon period. In the outer channel sector the salinity ranged from 1.60‰ in September when the flood water from the lake flows to sea, to 27.25‰ in April when there is inflow of sea water through the channel into the lake. The average depth varied between 164 cm in summer and 206 cm in monsoon period.

MATERIAL AND METHODS

Plankton samples were collected once in a month from 16 stations as shown in Fig. 1. Plankton for quantitative studies were collected by filtering 200 litres of water through a net made of No. 21 silk bolting cloth (72 meshes per cm). At times silt was present along with the plankton for which due allowance was made while noting down the volume of plankton in the samples. The samples were preserved in 4% formalin. The biomass of the plankton was

determined volumetrically and also numerically by using a Sedgwick-Rafter counting cell. The identification of phytoplankton was done up to genus only and of zooplankton up to major groups. However, some of the dominant planktters were identified up to the species. The data for salinity, phosphates and nitrates were taken from Sarkar (MS).

Plankton Biomass

The plankton biomass in different sectors showed somewhat similar pattern of fluctuation with a summer peak during April to June, a monsoon peak in July or August, a winter peak during October to December and a spring peak in February (Fig. 2). Taking the average for the entire lake there was a peak each

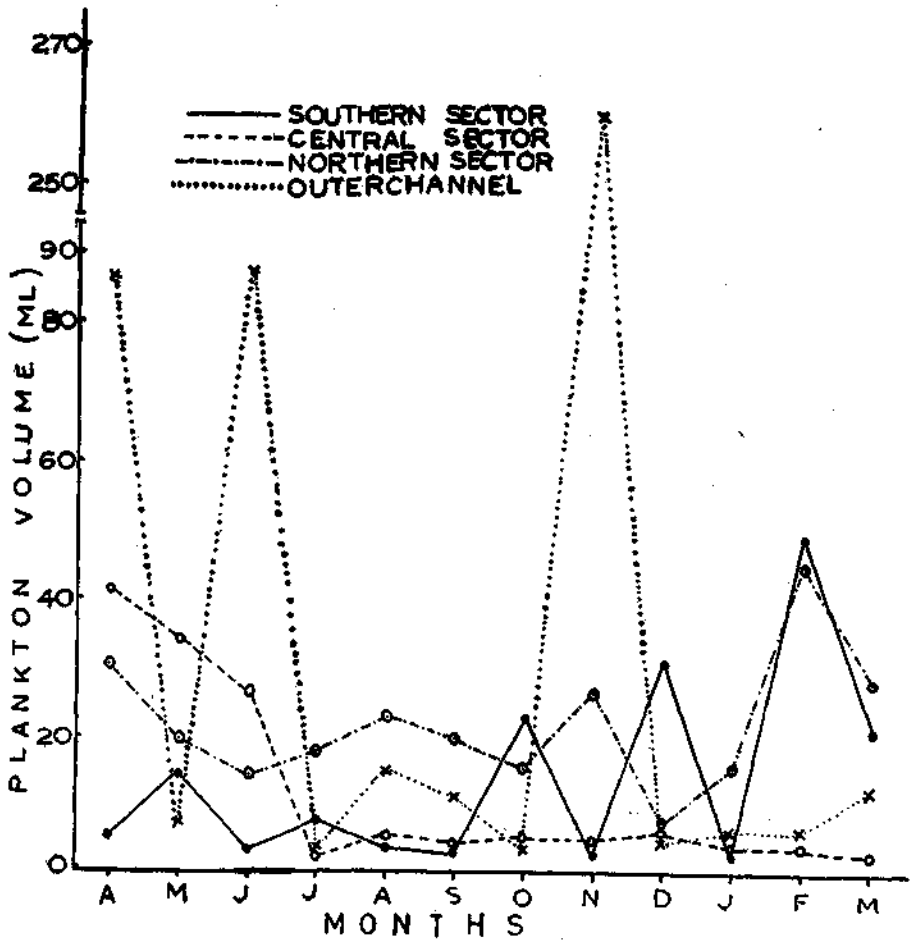

Fig. 2. Seasonal variation in the plankton volume in four different sectors of the Chilka Lake.

in April, August, November and February. The November peak was by far the most prominent one.

This broadly agrees with the observations made during 1958–1959 and 1959–1960 (Jhingran, 1963) except for an additional peak in February recorded now which was due to the phytoplankton bloom in the northern and southern sectors. The average plankton biomass was in the range of 0.006 to 0.073 ml/l.

PHYTOPLANKTON

The Phytoplankton population in Chilka Lake was constituted mainly by diatoms, blue-green algae, green algae and dinoflagellates. Taking the average number per litre for the whole lake it was observed that there were two peaks in March-June and November. Similar peaks in March, June and November were also recorded during 1959–1960 (Jhingran, 1963). The minima were noted during monsoon months July to October.

Taking sector-wise abundance the phytoplankton was comparatively poor in the northern sector where there were two peaks in November and March (Fig. 3). The November peak was a small one, mainly composed of blue-green algae in stations 3 and 4. The blue-green algae disappeared subsequently in December but re-appeared in greater abundance at the same two stations in February. In March their number increased and were recorded at all the 4 stations. After the monsoon, the salinity in this sector showed a steady rise from November and probably the nutrients brought in by flood water helped the formation of bloom.

In the central sector there was a single peak in May and during the rest of the months the phytoplankton crop was poor (Fig. 3). This peak was mainly recorded at stations 2 and 3 which were nearer to the opening of the outer channel and it is likely that the dominating diatoms and dinoflagellates of marine origin entered from the sea with the tidal flow. The stations 1 and 4, located in an area infested with dense weeds, were poor in respect of phytoplankton. The salinity peak coincided with the phytoplankton peak in this sector.

In the southern sector a single peak of phytoplankton was observed during March (Fig. 3). The high salinity in June and July in this sector does not show any correlation with phytoplankton. It was interesting to note that a single genus of diatom viz., *Chaetoceros* and blue-green algae viz., *Anabaena* mainly formed the peak. In different stations of the sector both these forms were recorded simultaneously. At Rambha, corresponding to the station 1, Roy (1954) recorded different members of diatoms but not the above forms. However, in July-October 1962, *Chaetoceros* were recorded in large numbers (Patnaik, MS).

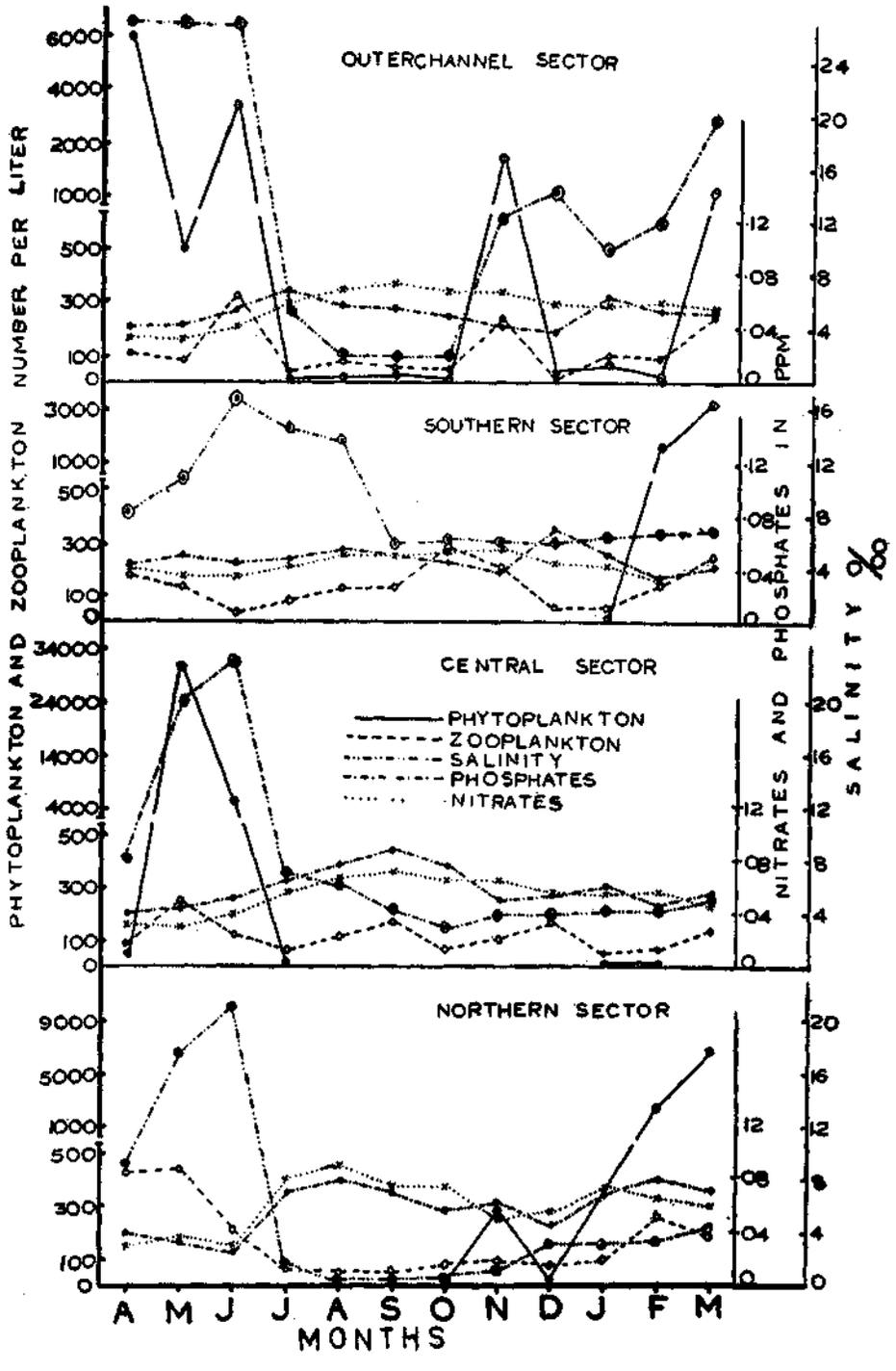

FIG. 3. Seasonal variations in phytoplankton, zooplankton, phosphates and nitrates in four different sectors of the Chilka Lake.

TABLE 1. *Monthly fluctuations in the chief groups of phytoplankton in different sectors given as units/litre*

Groups	Sectors	A	M	J	J	A	S	O	N	D	J	F	M
Myxophyceae	Northern	...	...	...	...	1	...	...	275	..	...	2275	6625
	Central	21	5	...	..	...	...	1	...	...	2	...	1
	Southern	3	2	...	1	1	1	...	...	...	1	446	1692
	Outer channel	1	7	57	2	...	3	4	124	20	11	...	40
Chloro-phyceae	Northern	...	1		...	...	2	5	...	1	...	...	1
	Central	1	...	3	...	..	...	...	...	...	...	...	...
	Southern	...	...		...	...	...	...	...	5	3	5	10
	Outer channel	...	...	...	...	11	25	2	15	1	9	1	1
Bacillari-ophyceae	Northern	1	...	6	...	1	...	...	2	1	...	1	...
	Central	13	30416	4973	...	...	...	...	1	1	3	7	...
	Southern	3	10	5	...	2	...	..	1	1	1	1068	1500
	Outer channel	59212	479	33518	2	5	1	...	13619	9	46	16	2029
Dinophyceae	Northern	...	...	...	...	...	...	...	...	...	...	...	...
	Central	...	3	4	4	...	...	...	...	..	...	...	...
	Southern	5	...	...	1	2	...	..	...	...	...	12	19
	Outer channel	53	17	42	...	...	...	...	11	1	2	...	55

In the outer channel sector the phytoplankton picture was quite different from the main area. Owing to the perennial sea connection there was regular ingress and egress of planktonic forms into and from the outer channel along with the tidal flow. As seen in Fig. 3 there was a summer peak in April which, after a short fall in May, showed a rise in June and this coincided with the salinity peak. The period of minima was noted during July to October when with the outflow of fresh water from the lake to the sea, the salinity dropped to its minimum and the tidal effect was the least. By November with the inflow of tidal water the salinity showed a rise and a peak of phytoplankton was observed which disappeared subsequently during December, January and February and appeared again in March. Taking the station-wise collections the highest number in April was from station 4 and lowest from station 1, whereas the position was just the reverse in June. No collection could be made from station 4 in July, September and October. The November peak was prominent at station 3 and also the March peak at station 4.

Diatoms—The diatoms formed 99.53%, 99.88%, 54.00% and 0.13% of phytoplankton in the outer channel, central, southern and northern sectors respectively. In all, 24 genera were recorded as against 19 genera reported by Roy (1954). From Table I it is noticed that the diatoms were very poor in the northern sector. This sector was characterised by high turbidity and wide fluctuations of salinity (Sarkar, MS) which probably inhibited their growth. The diatoms formed a peak during May to June in the central sector and during February to March in the southern sector. In the rest of the months they were either absent or present in fewer numbers in both the sectors. In the outer channel sector there were two peaks, one during April to June and the other during November. The data combined for the entire lake also showed the same two peaks which agree with earlier observations of Jhingran (1963) and Patnaik (MS). Similarly two diatom peaks have been reported from the Cochin Back-waters by George (1958) and from Hooghly Estuary by Shetty *et al* (1961). On the other hand Roy (1954) has reported a single summer peak from Chilka Lake in 1951-1952.

From the northern sector the diatoms recorded were *Pleurosigma* sp., *Campylodiscus horologium* Williams, *Coscinodiscus* sp. and *Planktoniella* sp. The diatom abundance in the southern sector during February and March was due to the species belonging to the genus *Chaetoceros* (*C. affinis* Lauder, *C. pendulus* Karsten and *Chaetoceros* sp.). The diatoms recorded from this sector were *Coscinodiscus* sp., *Planktoniella* sp., *Grammatophora* sp., *Pleurosigma elongatum* W. Smith, *Campylodiscus* sp. and *Bacillaria paradoxa* Gmelin. The diatoms in the central sector were also dominated by *Chaetoceros* (*C. perpusillus* Cleve, *C. peruvianus* Brightwell, *C. lorenzianus* Grunow and *Chaetoceros* sp.) forming 57.9% in May and 59.4% in June of the total diatom population. The next important form was *Asterionella japonica* Cleve which formed 25.3% of the diatoms in May and 33.0% in June followed by *Thalassiothrix frauenfeldii* Grunow which formed 16.0% in May and *Ditylum brightwellii* Grunow which formed 5.3% in June. The other forms recorded were *Coscinodiscus* sp., *Leptocylindus* sp., *Rhizosolenia alata* Brightwell, *R. setigera* Brightwell, *Biddulphia sinensis* Greville, *Bacteriastrum hyalinum* Lauder, *Pleurosigma* sp. and *Campylodiscus* sp. The diatoms were the most important group of plankton in all the stations of the outer channel sector. The April peak was dominated by *Chaetoceros* spp. (84.7%) followed by *Coscinodiscus* spp. (9.6%) and *A. japonica* (5.3%) whereas the June peak consisted chiefly of *Chaetoceros* spp. (49.1%), *A. japonica* (46.1%) and *Rhizosolenia* (2.5%). The winter peak in November was also dominated by *Chaetoceros* (84.4%), *B. hyalinum* (11.8%) and *Grammatophora* (1.8%). During March the diatom population showed an increase. The commonly encountered forms were *Chaetoceros* (33.8%), *B. hyalinum* (14.1%), *Nitzschia* spp. (10.6%), *A. japonica* (10.5%) and *Rhizosolenia* spp. (10.3%). It was noted that *A. japonica* was completely absent during winter. The earlier observation of Roy (1954)

and Patnaik (MS) also showed the same. Some of the diatoms of the outer channel sector identified upto species were: *Rhizosolenia stolterfothii* Peragallo, *R. alata*, *R. delicatula* Cleve, *R. fragillissima* Bergon, *Chaetoceros compressus* Lauder, *C. perpusillus* Cleve, *C. laciniosus* Schutt, *C. curvisetus* Cleve, *C. lorenzianus*, *C. diversus* Cleve, *C. coarctatus* Lauder, *Lauderia annulata* Cleve, *Thalassionema nitzschioides* Grunow, *Pleurosigma elongatum* W. Smith, *Surirella tenera* Gregory, *S. elegans* Ehr; *Biddu'phia sinensis* Greville, *Corethron hystrix* Hensen, *T. frauenfeldii*, *Skeletonema costatum* Cleve, *Nitzschia closterium* (Ehrenberg) W. Smith, *N. pungens* Cleve, *N. longissima Ralfs*, *N. seriata* Cleve and *Coscinodiscus granii* Gough.

Blue-green algae—Taking the annual average, this group constituted 99.76% of the total phytoplankton in the northern sector, 44.70% in the southern sector, 0.25% in tne outer channel sector and 0.08% in the central sector. In the northern sector *Anabaena* was the only genus recorded forming a bloom after the monsoon season. From the central sector stray numbers of *Lyngbya aestuarii* (Martens) Liebmann, *Oscillatoria laetevirens* (Crouad) Gomont and *Anabena* were recorded. In the southern sector the peak during March was mainly constituted by *Anabaena* and *Nostoc*. The other forms recorded from this sector in stray numbers were *Lyngbya aestuarii*, *Oscillatoria laetevirens and Phormidium* in different months. From the outer channel sector the dominant form *Trichodesmium erythraeum* Ehrenberg was recorded in more saline regions at stations 3 and 4 during November, December and March. The other forms recorded were *Oscillatoria* in May and June *Lyngbya*, *Anabaena*, *Phormidium* in other months.

Green algae—The green algae occurred in small numbers constituting 0.11% of the phytoplankton in the northern sector, 0.01% in the central sector, 0.50% in the southern sector and 0.06% in the outer channel sector during the year of study. The genus commonly recorded from the different sectors was *Spirogyra*. Stray records of *Chaetomorpha* and *Cladophora* from the central sector and *Enteromorpha* from the southern sector were also made.

Dinoflagellates—This group was completely absent in the freshwater zone of northern sector and constituted 0.03%, 0.80% and 0.16% of the phytoplankton population in the central, southern and outer channel sectors respectively. Their abundance in different sectors mostly coincided with diatom peaks. In the outer channel sector they were absent during July to October when the salinity was very low (0.05%). In the central sector they were restricted to May-July period only. *Ceratium* was the dominant genus recorded from all the sectors and some of the species were *Ceratium furca* (Ehrenberg), *C. tripos* Muller, *C. fusus* (Ehrenberg) and *C. longipes* (Bailey) Gran. In the central and outer channel sector *Noctiluca scintillans* Macartney and *Dinophysis caudata* Kent were recorded. *Peridinium diabolus* Cleve from the outer channel sector and another species of *Peridinium* from the southern sector were also recorded.

ZOOPLANKTON

Among the various zooplankton groups represented, copepods were the dominant forms constituting on an average 40.9% of the total, followed by nauplii 31.5% molluscan larvae 9.6%, protozoans 7.3%, rotifers 4.2%, polychaete larvae 2.7%, mysids 1.5% and the rest of the groups together about 2.3%.

As seen from Fig. 3, in the northern sector there were two peaks of zooplankton, one in May and the other in March. The May peak was due to abundance of copepods and nauplii at station 2. Similarly the February peak was mostly due to an increase in the population of rotifers, mysids and amphipods at stations 3 and 4. February to June was the period of zooplankton abundance in this sector and during monsoon period, July to October, zooplankton was scarce.

In the central sector also there was a peak of zooplankton in May which was due to the abundance of copepods, nauplii and tintinnids at stations 2 and 3. The second peak in September was mostly due to a large numbers of copepods, nauplii, rotifers and lamellibranch larvae from station 2. The third peak in December was due to overall increase in copepods and nauplii at all stations. The fourth peak in March was mainly composed of copepods and tintinnids at stations 2 and 4.

In the southern sector there were two peaks of zooplankton production, one in October and the other in March. The October peak was due to large numbers of copepods recorded from station 2, whereas in March, the zooplankton in general showed an increase in population.

In the outer channel sector the peak months of zooplankton abundance were June, November and March which coincided with phytoplankton peaks. (Fig. 3). The period of low salinity, July to October, coincided with lower abundance of zooplankton, possibly due to outflow of flood water from the lake through this sector. The June peak was dominated by the molluscan larvae and nauplii at all stations. In November the polychaete larvae and tintinnids were encountered in large numbers at station 4. The March peak, on the other hand, was due to an abundance of copepods, nauplii and tintinnids at station 1.

Taking the lake as a whole, the zooplankton showed a bimodal pattern of fluctuation with a peak in May (summer) and another in November (winter). Devasundaram and Roy (1954) have recorded the peak month of zooplankton to be July in 1950 and March in 1951. In the year 1959-1960 Jhingran (1963) recorded two peaks of zooplankton, one in November and the other in April, the former being more prominent.

The details regarding various groups of zooplankton are discussed below :

Protozoa—The tintinnids were most common from all the sectors except the northern. They were more numerous in the outer channel sector forming a

peak, each in June, November and March. The forms recorded most commonly were *Tintinnopsis*, *Cyttorocylis* and *Codonella* from the central and outer channel sectors and *Tintinnopsis* from the southern sector. The foraminifers were recorded from all over the lake in stray numbers.

Rotifera—They were more abundant in the freshwater zone - northern sector - during August to March with peak in February. In this sector an increase in the abundance of rotifera was noted in November, February and March at stations 3 and 4. In the central sector they were recorded in August to December period when the salinity was low. The common genera recorded were *Brachionus*, *Filinia* and *Keratella*.

Annelids—Larval polychaetes were recorded in the plankton mainly from the outer channel sector during March to June and November. From the central sector they were recorded from stations 2 and 3 during May and June when the tidal water usually enters through these stations.

Copepods—Copepods were the dominant group in the zooplankton during most of the months in all sectors. The minimum copepod abundance in the lake was recorded during the monsoon months. The highest number (550/l) was recorded from station 2 in the southern sector during October.

In the northern sector some of the freshwater copepods like *Diaptomus*, *Cyclops*, and *Mesocyclops* appeared in the collections during the monsoon period which gradually disappeared by January-February when the salinity increased. During summer and winter months the brackishwater forms *Pseudodiaptomus*, *Acartia*, *Nitocra* and *Oithona* dominated in the collections. In the outer channel sector during the same period some marine copepods like *Eucalanus*, *Labidocera* *Temora* and *Canuella* appeared in large numbers which probably entered from the sea along with the tidal water.

Amphipods—They were recorded in considerable numbers from the northern sector during summer and winter period and from the central and southern sectors in April and May. They were completely absent in the outer channel sector.

Mysids—The mysids were abundant in the northern sector and the month of maximum abundance was February. They were sparsely represented in other sectors. The dominant form was *Mesopodopsis orientalis* (Tattersall).

Decapods—Post-larvae of *Penaeus indicus* Milne Edwards and *P. monodon* Fabricius were recorded in insignificant numbers from the outer channel sector. *Lucifer* was recorded from all the sectors in different months except from the outer channel sector. It showed peaks in population during April and May in the northern and southern sectors respectively.

Molluscs—Larvae of lamellibranchs and gastropods were regularly represented in the plankton collections from all over the lake. The lamellibranch larvae were comparatively more common, being abundant in June in the northern and outer channel sectors, in May to July in the central sector, and in February and March in the southern sector. The gastropod larvae formed a peak during June in the central and outer channel sectors.

Fish eggs and larvae—They occurred sparsely in collections from all over the lake.

Other zooplankters—Some cladocerans like *Moina* occured during August to November in different sectors but disappeared when salinity increased. Ostracods, isopods, nematodes and cumaceans rarely occurred in the collections. Though chaetognaths have been recorded from the lake earlier (Jhingran, 1963) none belonging to this group was observed in the course of the present study.

Discussion

From the present investigation it is evident that, in general, plankton of Chilka Lake consisted of freshwater, brackishwater and marine forms which appear and disappear depending on the salinity conditions. The phytoplankton in the lake as a whole showed two peak seasons the principal one being from March to June (summer) with little fluctuations. The dominant forms were ***Chaetoceros*** spp. and ***Asterionella japonica***. The second peak season of short duration in November (winter) was possibly due to the rapid vegetative multiplication consequent on the rise of salinity and richness of nutrients in the water after monsoon as reported by Subrahmanyan (1960) for Gulf of Mannar. The main forms recorded were ***Chaetoceros*** spp. and ***Bacteriastrum hyalinum***. The zooplankton crop for the whole lake also showed two maxima closely following the phytoplankton and the copepods formed the bulk of the zooplankton.

The extent of tidal influence in the main body of the lake was noticed as far as stations 2 and 3 in the central sector which was indicated by the presence of similar neritic planktonic forms in these two stations and the outer channel stations. The peak of blue-green algae in the northern sector during November, February and March followed the flood season when natural enrichment of water took place.

During monsoon period (July to October) the water level in the lake usually rose resulting in considerable dilution and was characterized by low salinity (Fig. 3). Jhingran (1963) recorded high turbidity values during May to September and minimum plankton production during July and August in 1957-1960 from Chilka Lake. Sarkar (MS) recorded high turbidity values during July to October 1964 from Chilka Lake. The phytoplankton population was also observed to be low during July to October in the present investigation. Similar low yield of

phytoplankton during monsoon period was reported by Roy (1955) from Hooghly Estuary. Legare (1957), Welch (1952) and Dutta *et al.* (1954) reported high turbidity accompanied with low production of plankton. Berner (1951), Bainbridge (1960) and Ray *et al.* (1966) also mentioned that abundance of plankton was influenced by the dilution effect during monsoon period. In Chilka Lake both high turbidity and sudden dilution by the influx of fresh water could be responsible for the low production of plankton during July to October.

It is observed that the salinity did not show any direct correlation with the plankton peaks. However, in the northern sector freshwater forms which entered along with flood water disappeared with rise of salinity from January onwards. Similarly in the outer channel sector with the rise of salinity many marine forms appeared. Phosphates and nitrates showed no distinct relationship with phytoplankton or zooplankton abundance, though in the northern and central sectors, increase of these factors was seen during flood season.

Among various investigators Anderson *et al.* (1955), Harvey *et al.* (1935) and Wright (1958) have recorded inverse relationship between phytoplankton and zooplankton. However, there are also records of direct relationship (Kow, 1953 and Subrahmanyan, 1959). Martin (1965) attributes the seasonal abundance of phytoplankton to differential grazing pressures by zooplankton. In the present study however no definite correlation is discernible, the relationship being some times direct and some other times indirect. This may be due to the fact that the Chilka Lake is not a closed ecosystem and is subjected to tidal currents and inflow of flood water.

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