Hydrobiologia **197**: 245–256, 1990.
F. A. Comin and T. G. Northcote (eds), Saline Lakes.

Comparative limnology of Sambhar and Didwana lakes (Rajasthan, NW India)

G.R. Jakher, S.C. Bhargava & R.K. Sinha
Department of Zoology, University of Jodhpur, Jodhpur, India

Key words: saline lakes, plankton, primary productivity, salt tolerance

Abstract

Two alkaline saline inland lakes of Indian arid region were studied during 1984 and 1985, to assess functioning and interaction of various environmental and biological factors. Changes in physical and chemical variables, planktonic composition, chlorophyll content and phytoplankton primary productivity were examined.

Salinity in both lakes fluctuated from almost fresh water (1.80‰), to hypersaline (300‰) and acted as the main controlling factor for almost all the biotic parameters. Maximum total alkalinities were 2162 mg l^{-1} and 2090 mg l^{-1}, respectively in Sambhar and Didwana lakes. Dissolved oxygen ranged from completely anoxic conditions to maxima of 11.68 and 7.29 mg l^{-1}, respectively in Sambhar and Didwana lakes. Nutrient enrichment in the lakes was low.

The phytoplankton species composition of Sambhar lake was reduced from an earlier reported 20 genera to only 11 (*Nostoc*, *Microcystis*, *Spirulina*, *Aphanocapsa*, *Oscillatoria*, *Merismopedia*, *Nitzschia*, *Navicula*, *Synedra*, *Cosmarium* and *Closterium*). Phytoplankton of Didwana was composed of only 9 genera including *Anabaena* and *Nodularia*. Sambhar lake, which once contained *Artemia*, is now totally devoid of them. On the other hand, *Artemia* was the most dominant zooplankter in Didwana lake at a salinity range of 15–288‰. Other zooplankters such as *Moina*, *Cyclops* and *Brachionus* flourished at lower salinity levels in Didwana lake. The seasonal quantitative and qualitative phyto- and zooplankton changes in relation to salinity are documented.

Introduction

The main inland alkaline and saline water bodies of the Indian arid region are Sambhar and Didwana lakes, of which the former is the largest. Sambhar Lake has been subjected to extreme conditions varying from immense floods to long dry periods. This lake, which once supported a rich population of brine shrimp, *Artemia*, became totally devoid of it during 1977–78 (Alam, 1980). This has been a consequence of a drastic decrease in salinity due to repeated floods in the region during the last decade, which also resulted in the introduction of a variety of freshwater biota including predatory fishes from tributary rivers. According to Williams (1964), this lake was hypersaline (50‰) during 1956–67 (Baid, 1962, 1969) but it became hyposaline (16‰) in 1977–79 (Alam, 1980) and no has again regained high salinity levels.

Didwana Lake is of great interest as it is the only existing natural inland biotope of the brine

shrimp *Artemia* in India (Bhargava *et al.*, 1987a) and the importance of *Artemia* as a high quality live food in aquaculture is well known.

The present study of Sambhar and Didwana lakes was undertaken to follow the important changes in the biocoenosis of these lakes in relation to changes in salinity and other environmental factors and to explore the possibility of reintroducing *Artemia* to Sambhar Lake.

Description of sites studied

Sambhar lake

Sambhar Lake (27° 58′ N, 75° 55′ E) is in a shallow depression, in the Nagaur and Jaipur districts of State of Rajasthan, NW India (Fig. 1). It is about 22.47 km long and 3.21 to 11.23 km in width. At maximum depth its total surface area is about 190 km^2. The maximum depth of the lake was 3 m, recorded in the early part of this study. The surrounding area is sandy and sterile, with the Indian desert on the western side. The lake is rainfed, and receives water from a large catchment area of about 471 km^2.

Besides a rich planktonic flora and fauna, eight freshwater fish species (*Puntius sophore*, *Labeo bata*, *Labeo gonius*, *Oxygaster bacaila*, *Channa punctatus*, *Mystus seenghala*, *Saccobranchus fossilis* and *Chanda nama*) were recorded from the lake just after the monsoon of 1983, when the salinity declined to 1.84‰. These fishes found their way into the lake through incoming streams carrying water of overflowing freshwater ponds and reservoirs in the catchment area. However, the fishes could not survive after the salinity increased above 9‰.

Didwana Lake

Didwana Lake is 70 km west of Sambhar Lake (Fig. 1). At maximum depth it is 6.5 km long and 2.5 km wide, covering an area of 16.5 km^2. Maximum depth of the lake was 5 m during this study. The lake was devoid of macrophytes and nektonic fauna. Flocks of flamingos (*Phoenicopterus roseus*) and solitary Indian black winged stilts (*Himantopus himantopus*) inhabit the lake.

Material and methods

The investigations were carried out at Sambhar Lake from February 1984 to January 1985 and at Didwana Lake from December 1983 to January 1985, though it was dry from May to August in 1984. Water samples were collected monthly from each lake (Fig. 1). Chemical determinations were done according to APHA (1975). Phytoplankton were studied after sedimentation and zooplankton after filtering water through a standard bolting silk plankton net (0.3 mm mesh size). Primary production of the phytoplankton was estimated *in situ* by the ^{14}C method (Vollenweider, 1969) and the chlorophyll content determined according to Strickland & Parsons (1972).

Results

Sambhar Lake

Table 1 provides mean monthly values of various physical and chemical variables of Sambhar Lake. No data could be recorded during June 1985, as the lake was dry.

The pH remained highly alkaline, ranging from 8.8 to 9.7. Carbonate alkalinity increased with the rise in salinity and varied from 64 mg l^{-1} (February 1984) to 872 mg l^{-1} (May 1985). Bicarbonate alkalinity dominated throughout the study period, ranging from 144 mg l^{-1} (February 1984) to 1290 mg l^{-1} (May 1985).

Between 1974 and 1983 repeated floods in the region resulted in the dilution of the lake brine and the salinity along with the potential for salt production went down remarkably. During the present study the salinity fluctuated widely, from a initial value of 5.14‰ (February 1984) to a maximum of 267.3‰ (May 1985). The term salinity herein refers to that derived from chlorinity values. Dissolved oxygen varied in relation to

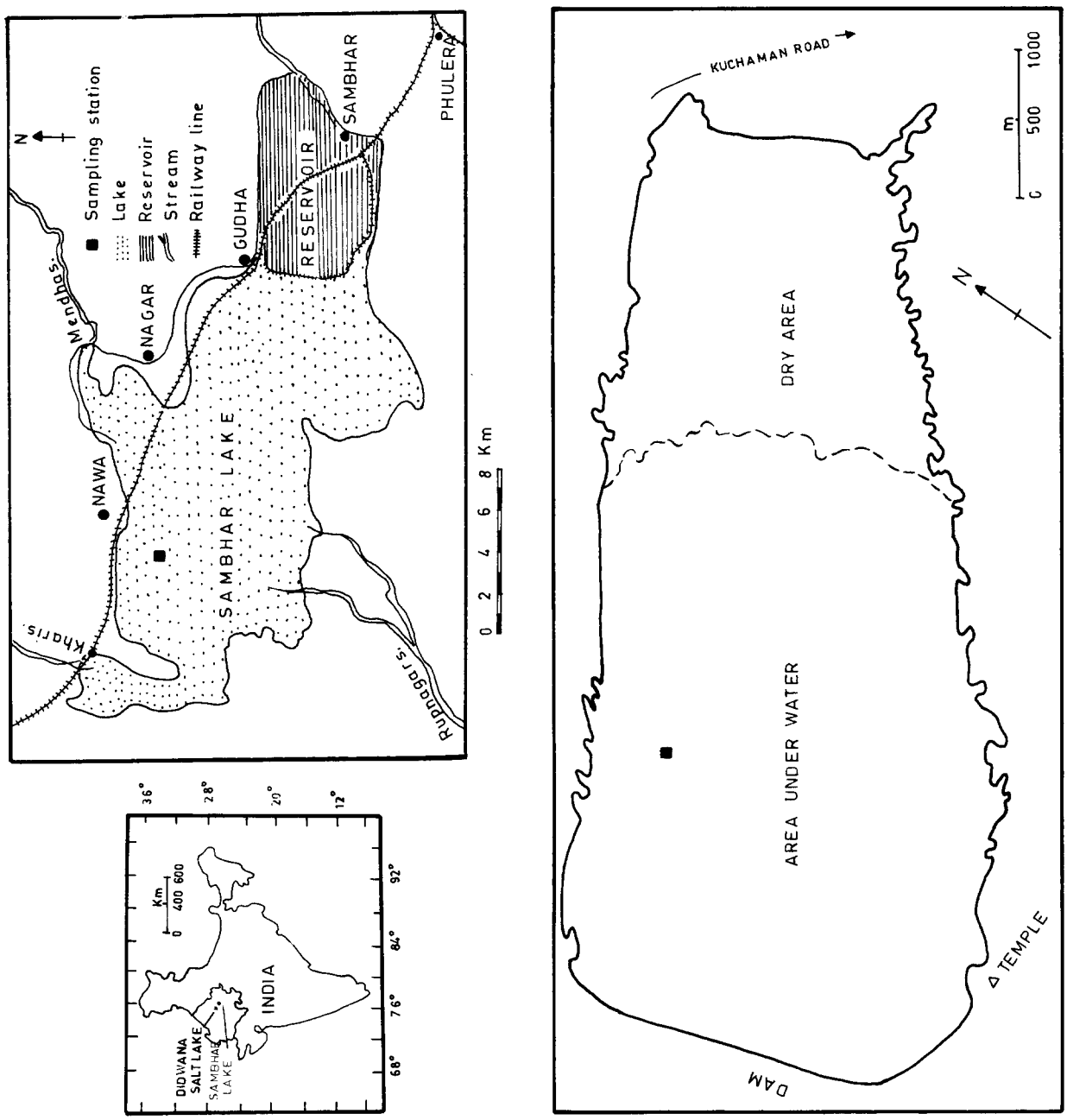

Fig. 1. Sambhar and Didwana lakes. Geographical setting and sampling location.

salinity, with a maximum of 11.52 mg l^{-1} when salinity was low and was completely depleted when salinity increased above 100‰. The ionic fractions of cations, Na, K, Ca and Mg and the anion SO_4 and Cl^- estimated from October 1984 to September 1985, are summarized in Table 2.

Nutrient enrichment of the lake was rather low, except that of nitrate which exhibited a wide range

Table 1. Mean values of abiotic variables in Sambhar Lake.

Month	Water T (°C)	pH	Dissolved oxygen mg l^{-1}	Salinity ‰	Nitrate μg-at l^{-1}	Phosphate μg-at l^{-1}	Silicate mg l^{-1}
Feb '84	20	9.6	11.52	5.14	29.36	–	1.74
Mar '84	26	9.6	9.26	11.74	36.66	0.45	2.42
Apr '84	26	9.0	11.58	12.90	64.16	1.35	3.6
May '84	24	8.8	1.91	13.8	90.83	2.40	4.23
Jun '84	32	9.0	4.63	15.35	101.66	2.62	4.61
Jul '84	28	9.0	4.48	16.25	137.2	3.15	4.90
Aug '84	24	8.8	8.47	18.06	175.0	3.00	4.45
Sep '84	24	8.8	6.87	21.60	221.2	3.6	4.7
Oct '84	19	9.2	4.31	27.09	238.0	4.2	3.25
Nov '84	18	9.2	6.86	33.40	–	5.7	2.3
Dec '84	21	9.4	6.24	47.87	–	6.96	2.62
Jan '85	20	9.4	4.80	56.0	–	3.3	5.02
Feb '85	14	9.5	2.40	60.50	–	13.50	7.05
Mar '85	19	9.4	0.64	112.90	49.99	4.5	6.6
Apr '85	23	9.7	0.85	198.72	69.90	24.0	4.15
May '85	22	9.7	–	267.36	–	–	–
Jun '85	–	–	–	–	–	–	–
Jul '85	29	9.0	–	2.06	106.6	0.8	0.09
Aug '85	25	9.1	–	48.77	–	8.15	0.26
Sep '85	31	9.1	–	176.13	–	7.96	–

of fluctuation from nil to 238 μg-at l^{-1}. Orthophosphate was initially absent but appeared in March 1984 and gradually increased to attain its maximum concentration by April 1985 (24 μg-at l^{-1}). Silica was present in low concentrations, ranging from nil to 8.75 mg l^{-1}.

The maximum phytoplankton population (5256 × 10^3 cells l^{-1}) was observed in July 1984

Table 2. Mean monthly values of cations and anions in Sambhar Lake.

Month	Alk. mg l^{-1}	Chloride mg l^{-1}	Sulphate mg l^{-1}	Sodium mg l^{-1}	Potassium mg l^{-1}	Calcium mg l^{-1}	Magnesium mg l^{-1}
Oct '84	1172	15.0	249.0	3793.85	0.273	16.03	10.94
Nov '84	962	18.5	321.80	6092.35	0.93	80.16	34.04
Dec '84	1247	26.5	326.6	31609.46	23.06	32.06	58.36
Jan '85	1301	31.0	273.77	35748.08	32.06	40.08	51.07
Feb '85	1620	33.5	297.78	41325.74	16.42	60.12	116.73
Mar '85	1750	62.5	220.93	53789.18	19.15	36.07	63.23
Apr '85	2045	110.0	312.990	78723.75	29.12	36.07	104.57
May '85	2162	148.0	307.39	14012.65	31.28	36.07	107.00
Jun '85	–	–	–	–	–	–	–
Jul '85	234	1.0	–	899.8	1.95	20.04	–
Aug '85	640	27.0	–	10046.65	14.46	32.06	65.55
Sep '85	965	67.0	–	57431.50	17.59	29.30	–

at the salinity of 16.25‰ (Fig. 2). Blue-greens formed the dominant group and contributed the most genera. Among the blue-green algae *Nostoc* tolerated a salinity range from 5.1 to 47.8‰ and formed the major part (45.8%) of the total phytoplankton population during April to October 1984. *Spirulina* showed the maximum salinity tolerance (5.1–198.7‰) and was found throughout the study period except near the end of the investigation. *Spirulina* formed the highest percent composition (33.4–99.6%) in the salinity range of 33 to 198.7‰. *Aphanocapsa* and *Oscillatoria* first appeared when salinity reached 27‰ and disappeared when salinity exceeded 112.9‰ (Fig. 3). Other two blue-green algae, *Microcystis* and *Merismopedia* were observed only during early part of study when salinity ranged 5.1–13.8‰. The diatoms *Nitzschia*, *Navicula* and *Synedra* occurred in a salinity range of 15.3 to 47.8‰ and represented only a small portion (0.34–7.34%) of the total population. Chlorophyceans were represented only by two genera, *Cosmarium* and *Closterium*, appeared only once during the study period and *Cosmarium* was only found in few 1984 samples, forming 0.1–4.6% of the total density.

Primary production was maximum (gross production 11.52 g C m^{-3} day^{-1}; net production 7.88 g C m^{-3} day^{-1}) in April 1984 at 12.9‰ salinity (Fig. 2). Primary production was related more to chlorophyll concentration than to number of cells of phytoplankton (Fig. 2).

Total chlorophyll concentration ranged from nil (last part of the study) to 30.30 mg m^{-3} in

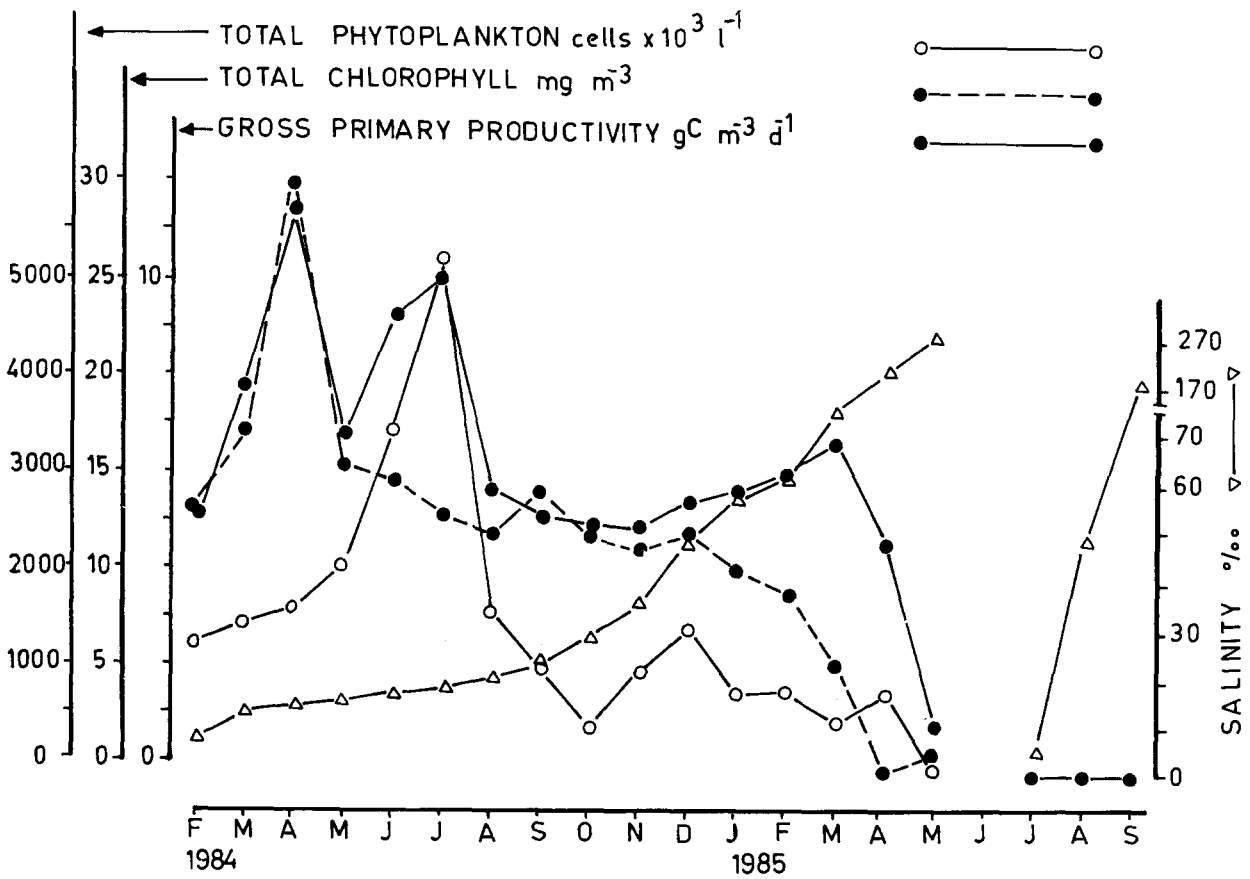

Fig. 2. Monthly variations of total phytoplankton density, total chlorophyll concentration and primary productivity in Sambhar lake.

Table 3. Mean monthly values of various variates at three stations in Didwana Lake from december 1983 to January 1985. Lake dry from May to August.

Parameters	Months									
	D	J	F	M	A	S	O	N	D	J
Water Temperatura (°C)	16.0	13.0	15.3	20.0	25.0	24.0	24.0	18.5	17.7	19.0
pH	8.4	8.7	9.0	9.5	10.0	8.7	8.99	8.6	8.4	7.8
CO_3 (mg l^{-1})	146.0	177.0	209.5	290.5	498.5	48.5	145.5	150.5	226.7	
HCO_3 (mg l^{-1})	372.5	450.0	626.0	1064.5	1574.0	158.5	180.0	275.0	374.2	391.5
Alkalinity (mg l^{-1})	518.5	627.0	835.5	1355.0	2072.5	207.0	325.5	425.5	600.9	391.5
Dissolved oxygen (mg l^{-1})	7.1	5.0	0.5	0.6		5.6	4.7	4.2	1.8	
Sodium (mg l^{-1})								13983.7	55946.3	98923.7
Potassium (mg l^{-1})								38.0	79.1	101.7
Calcium (mg l^{-1})								51.2	86.2	115.5
Magnesium								56.1	109.7	139.4
Chloride ‰ (ppt)	21.6	35.8	45.7	67.6	121.5	8.1	19.2	39.0	112.3	183.0
Sulphate (mg l^{-1})								228.1	309.7	298.1
Salinity (‰)	46.3	64.8	82.6	120.4	237.5	15.7	34.7	70.4	203.0	336.0
Nitrate (μg-at l^{-1})		28.9	33.6	56.8	62.4	51.9	40.7	36.4	73.9	119.9
Nitrite (μg-at l^{-1})		0.1	0.0	0.2	0.9	0.0	0.1	0.0		
Phosphate (μg-at l^{-1})		1.0	1.6	2.1	2.9	2.0	0.9	3.8	6.8	10.3
Silica (mg l^{-1})		0.4	0.4	1.6	4.0	0.3	1.1	2.5	2.5	5.0

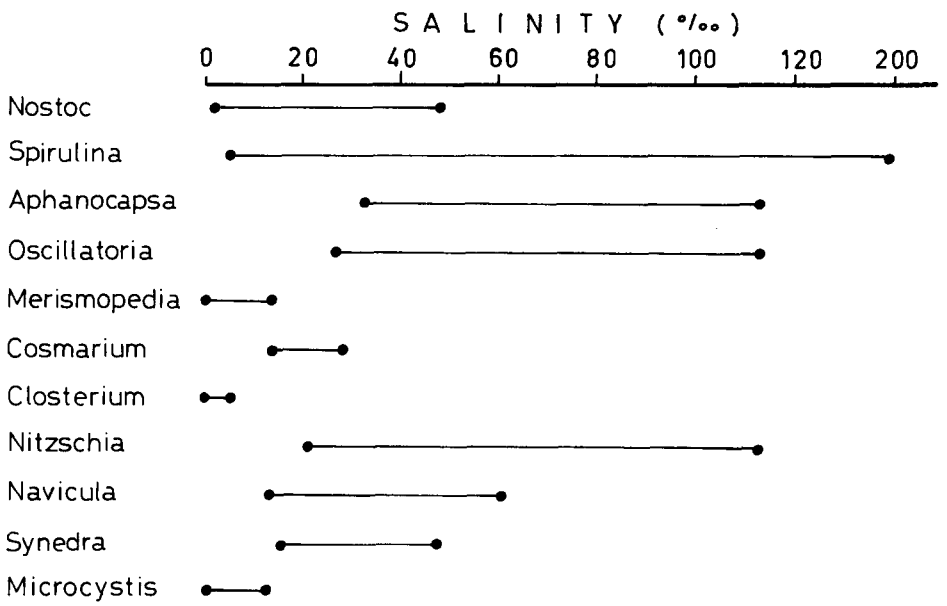

Fig. 3. Occurrence of various phytoplankton taxa in relation to salinity in Sambhar lake.

April 1984 (Fig. 2). Chlorophyll *a* was the dominant pigment whose concentration ranged from nil to 15.87 mg m^{-3}. Chlorophyll *c* was found in the lowest concentration among the chlorophylls. Carotenoids also occurred regularly except during the last four months of the study.

The maximum value (37.45 mg m^{-3}) was recorded in April 1984, coinciding with the highest peak of total chlorophyll.

The lake supported a poor population of zooplankton, quantitatively as well as qualitatively. The zooplankton density was low in April 1984, when the salinity was less than 13‰ (Fig. 4), but increased to the highest level in July (315 individuals l^{-1}) when fishes were no longer present. *Cyclops* and *Brachionus* were the dominant genera and occurred the whole salinity range observed. Other forms like *Moina* and nauplii showed an erratic distribution and *Diaptomus* was found only once (July 1984). However, when salinity exceeded 56‰, all zooplanktonic forms disappeared.

Didwana Lake

Didwana Lake was highly alkaline (Table 3), with pH ranging from 7.6 to 10.2. The highest pH was recorded in April 1984, probably an effect of high carbonate and bicarbonate content. Carbonate and bicarbonate concentrations varied from 18 to 510 mg l^{-1} and 70 to 1580 mg l^{-1} respectively. Total alkalinity was high (437 to 2090 mg l^{-1}). Dissolved oxygen concentration varied from complete anoxia to 7.29 mg l^{-1}, declining with increased salinity.

Salinity ranged from hyposaline (7.5‰, September 1984) to hypersaline (336‰, January 1985). Highest salinities were recorded when the lake had nearly dried up and approached the saturation point. The major ions present were sodium and chloride with the sequence of ionic dominance being $Na > Mg > Ca > K$ and $Cl > HCO_3 > CO_3 > SO_4$. Ionic fractions in milliequivalent percentages were as follows: Cations, Na 98.61, K 0.21, Ca 0.40, Mg 0.76; anions, Cl 98.60, SO_4 0.59, HCO_3 0.39 and CO_3 0.30.

Nutrients were found in low concentrations. Nitrate ranged from nil to 120 μg-at l^{-1}. The maximum values were recorded on two occasions (April 1984 and January 1985) just before the lake dried up. This was perhaps due to algae decay following high salinities and subsequent nitrification. Orthophosphate concentrations showed wide fluctuations, particularly after the dry period (May–August 1984). It ranged from nil to 11.15 μg-at l^{-1}, and like that of the nitrate, the maximum concentration was recorded when the lake was on the verge of drying up. Reactive silicate was the dominant nutrient (0.50–5.02 mg l^{-1}).

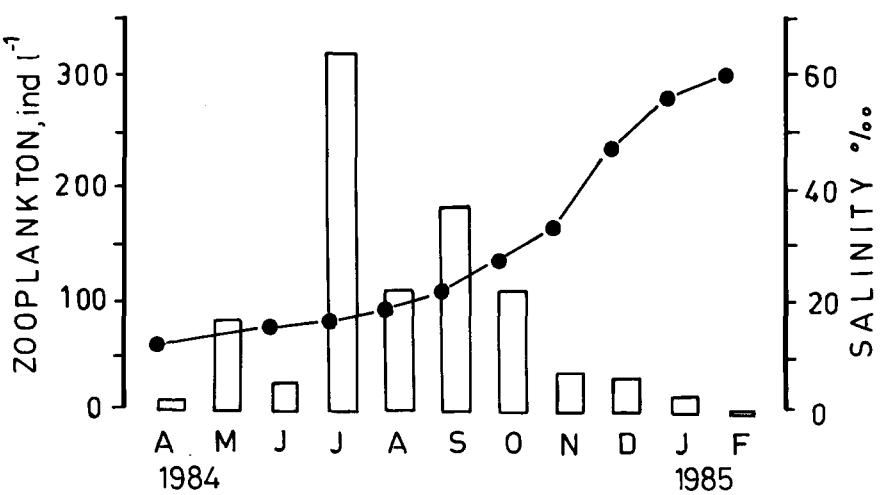

Fig. 4. Monthly variations of total zooplankton density in relation to salinity changes in Sambhar lake.

In Didwana Lake there were relatively few phytoplankton taxa and their total density ranged up to 3991 × 10^3 cells l^{-1} (Fig. 5). Only 9 genera were recorded from this lake. Six were blue-greens (*Aphanocapsa*, *Microcystis*, *Nostoc*, *Anabaena*, *Nodularia* and *Spirulina*), two diatoms (*Nitzschia* and *Synedra*) and one chlorophycean (*Closterium*). The maximum density of phytoplankton was observed at 34.7‰ salinity in October 1984 (Fig. 5). A *Spirulina* bloom occurred just preceding the dry period in April 1984.

Aphanocapsa was the most abundant alga in this lake and it occurred over a wide range of salinity. Maximum counts (1539 × 10^3 cells l^{-1}) were recorded in November 1984, when salinity was 62‰ and it occurred even up to a salinity of 146‰. *Microcystis* was the next dominant alga numerically. *Spirulina* showed the greatest salinity tolerance, from 7.54 to 178.84‰ (Fig. 6), and *Nitzschia* also represented up to a salinity level of 146.6‰. *Synedra* had a low salinity range (Fig. 6).

The order of dominance of chlorophyll pigments was $a > c > b$. Highest total chlorophyll content (29.33 mg m^{-3}) was concomittant with the maximum total phytoplankton population (Fig. 5).

Gross phytoplanktonic productivity was low, the maximum being 5.1 g C m^{-3} d^{-1} (Fig. 5). The average daily gross production was estimated 2.12 g C m^{-3} d^{-1} in 1984. Net primary productivity ranged from nil to 2.8 g C m^{-3} d^{-1}. On an annual basis (1984) gross and net primary

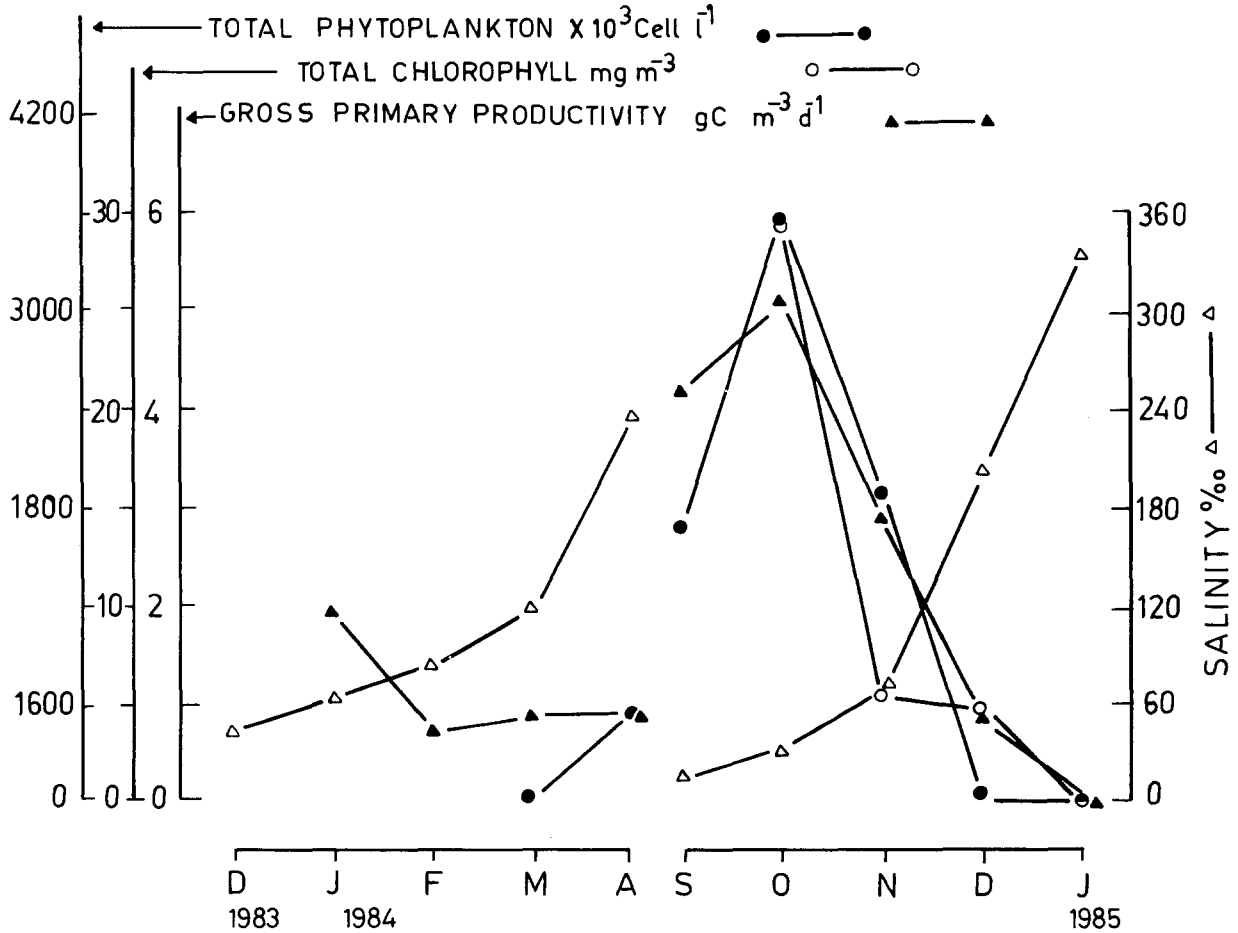

Fig. 5. Monthly variations of total phytoplankton density, total chlorophyll concentration and primary productivity in Didwana lake.

productions were 781.10 g C m^{-3} y^{-1} and 416.10 g C m^{-3} y^{-1} respectively.

Salinity and temperature appeared to have important effects on the occurrence, abundance and growth of zooplankton, particularly of the brine shrimp, *Artemia*. In the beginning of the study (December 1983), when the salinity of the lake was 39.7‰, two crustaceans *Moina* sp. and *Cyclops* sp. and a rotifer *Brachionus* sp. were present but in small numbers. As the salinity increased to 87.9‰ (late February 1984), these forms disappeared and were succeeded by *Artemia* in its various stages of development (Fig. 7). Its numbers increased rapidly attaining a high population of 1308 individuals l^{-1} by March 1984 (salinity 94.2‰). However, brine shrimp population declined when the salinity reached 200‰ and at 270‰ no adults or juveniles were found (Fig. 7). At that time a dense accumulation of *Artemia* cysts was seen along the shore of the lake.

After a dry period of 4 months, young stages of brine shrimp appeared soon after rains began in September 1984, when the salinity had dropped to 15.7‰. At this low salinity other zooplanktonic forms such as *Moina* sp., *Cyclops* sp., *Brachionus* sp. and insect larvae reappeared and replaced *Artemia* which apparently could not survive at the low salinity (Fig. 7). When the salinity increased to 77.68‰ (November 1984), all the other zooplankters disappeared and were succeeded again by *Artemia* which persisted this time until the salinity reached 288‰.

Discussion

High salinities in both Sambhar (267.3‰) and Didwana (336‰) lakes in 1985 can be attributed to extremely low rainfall and high rate of evaporation. During the previous thirty years, the salinity of Sambhar Lake fluctuated turning the lake from hypersaline to subsaline and back to hypersaline levels (Baid, 1958, 1969; Alam, 1980). Baid (1962) reported maximum salinity in Sambhar lake to be 164‰ which contrasts with 15.22‰ during 1977–78 (Alam, 1980).

Various salts dissolved in water lower its ability to absorb and hold oxygen (Cole, 1979). Hence highly saline waters have low dissolved oxygen -D.O.- concentration. During the present study also D.O. was found inversely correlated with salinity. Dissolved oxygen concentrations recorded ranged from nil to as high as 11.68 mg l^{-1} in Sambhar Lake. In the earlier studies on Sambhar

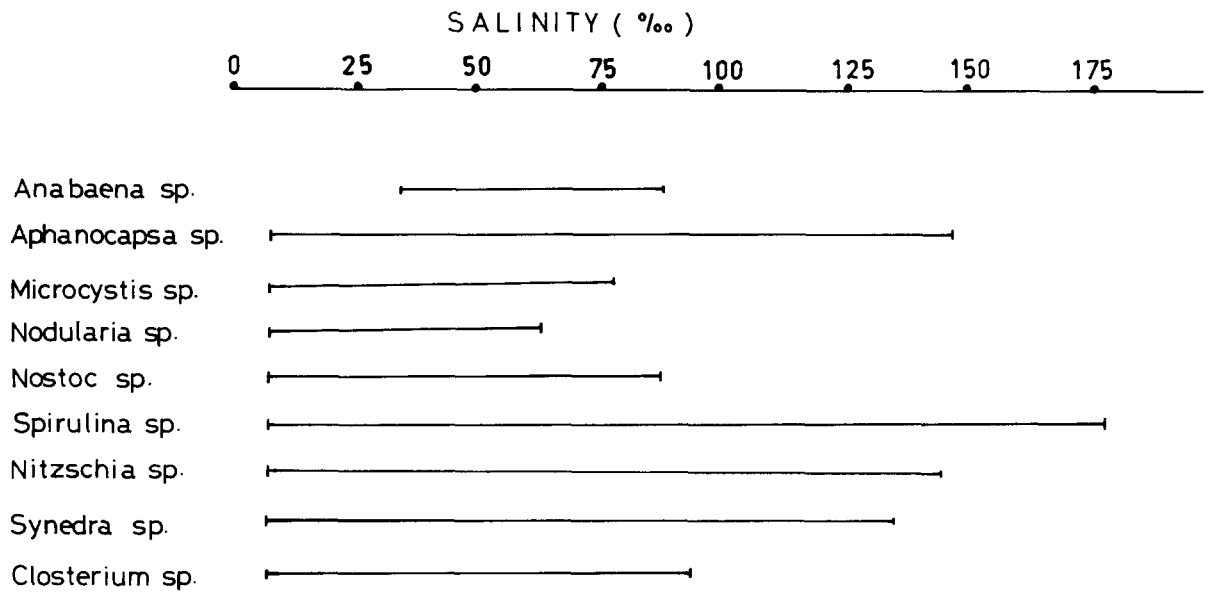

Fig. 6. Occurrence of various phytoplankton taxa in relation to salinity in Didwana lake.

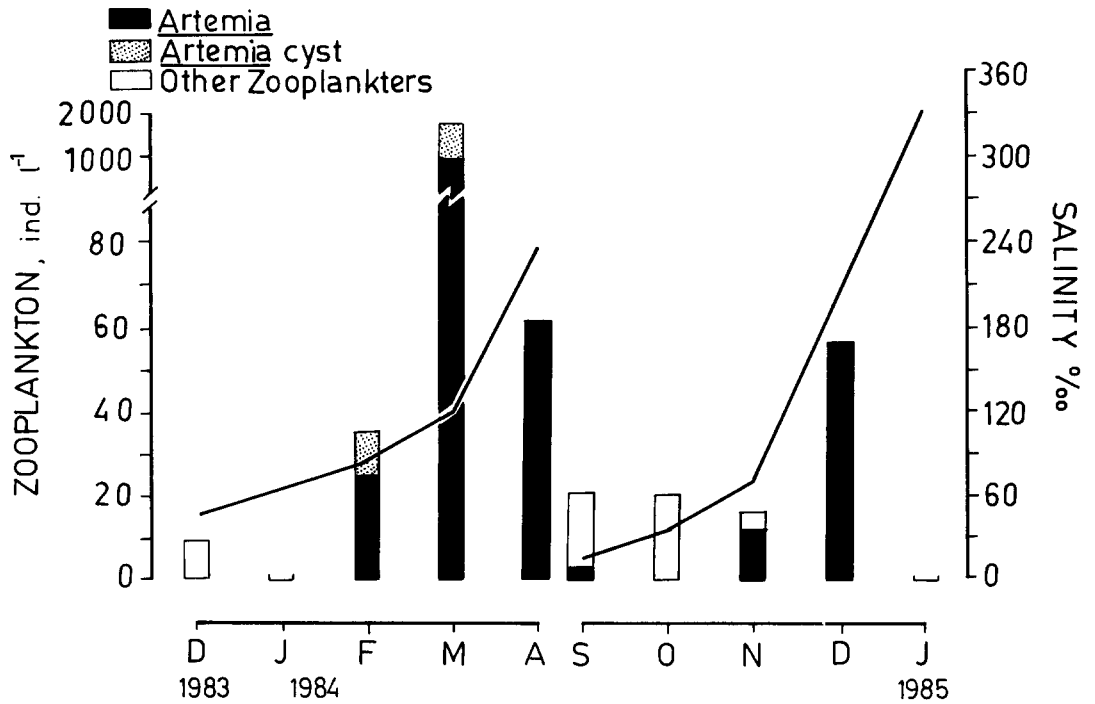

Fig. 7. Monthly variations of total zooplankton density in relation to salinity changes in Didwana lake.

Lake, Baid (1962) reported a range of 9.68–31.46 mg l^{-1} (although Baid himself was doubtful about such high abnormal values) and Alam (1980) 1.57 to 7.28 mg l^{-1}. But complete depletion of D.O. was found for the first time during the present study. The very high salinity may prevent the healthy growth of phytoplankton and thereby lowering the photosynthetic activity and release of oxygen, increasing oxygen consumption for organic matter decomposition.

The ionic composition of the total salinity of Sambhar and Didwana lakes are very similar. Other saline lakes all around the world show a high dominance of sodium and chloride (Bayly, 1969; Topping & Scudder, 1977; Williams, 1978; Comín *et al.*, 1983) at different salinities. Goldman & Horne (1983) gave support to the idea of biological diversity limited by high sodium concentrations due to osmotic stress, which also holds good in the case of Sambhar and Didwana lakes.

Nutrient concentrations in Sambhar Lake showed higher range during the present study in comparison to earlier one (Alam, 1980). In both Sambhar and Didwana lakes phosphate showed an increasing trend with the increase of salinity, while at the same time it was paralleled by decrease of phytoplankton populations, due to high salinity. Silicate concentrations were lower than in other saline lakes elsewhere (e.g. Rawson & Moore, 1944).

Sambhar Lake had higher phytoplankton density than Didwana Lake and also varied in qualitative composition. This agrees with the heterogeneity observed in salinity and chloride concentrations that were generally higher and changed quicker in Didwana Lake. Alam (1980) recorded 20 phytoplanktonic genera from Sambhar Lake during 1977–78. Total phytoplankton population over that period ranged from 150×10^3 to 9230×10^3 cell l^{-1}. The lower density and number of species observed in our study may be due to greater change in salinity range.

Comparing data from Baid (1962, 1969) and

Alam (1980) with our data it is evident a change in phytoplankton composition of Sambhar Lake. Genera *Chlamydomonas*, *Dunaliella* and *Aphanotece* which inhabited the Sambhar Lake during 1962–1969 are not found thereafter. During 1977–78, when salinity ranged only 6.86 to 15.22‰, maximum diatoms genera (11) were reported, out of which only three genera were found in Sambhar Lake and two in Didwana Lake during the present study. One species of the blue green *Oscillatoria*, which prevailed during 1962–69 (Baid, 1969), has been observed during present study from Sambhar Lake.

Species number decreased in Sambhar and Didwana lakes as salinity increased. A high carbonate concentration has also been mentioned as a limiting factor for many algal species, because it can be the reason for absence of free CO_2 (Hammer *et al.*, 1983). Low species number has also been reported from many other saline lakes around the world (Gessner, 1957; Walker, 1973; Post, 1975; Vareschi, 1982).

Primary productivity of Sambhar Lake showed two peaks below 20‰ salinity but thereafter declined. The maximum of both gross and net primary production synchronized with the monsoon peak of phytoplankton in Didwana Lake (Fig. 5). Similar relationship was indicated by Haynes & Hammer (1978) for saline lakes of Canada. Total chlorophyll also showed inverse relationship with the salinity. In present study of Sambhar Lake different chlorophyll pigments *a*, *b* and *c* showed higher concentrations than those reported earlier by Alam (1980).

The disappearance of *Artemia* and *Branchinella* from Sambhar Lake (Alam, 1980) can be attributed to dilution of brine or to the arrival of predators and change in food resources. Lakes Didwana and Sambhar have similar crustacean and rotifer species. *Artemia* is also present in Lake Didwana but not in Sambhar Lake. However, Tiwari (1958) and Baid (1958) recorded, respectively, *Branchinella* and *Artemia* in Sambhar Lake. Since the salinity of Sambhar Lake has regained a moderately high level and no predators occur, an attempt can be made to reintroduce the brine shrimp in this lake environment. To begin with, rearing trials with *Artemia* from Didwana Lake have been carried out in a salt pan near Sambhar Lake (Bhargava *et al.*, 1987b).

Acknowledgements

This study was carried out under a Man and Biosphere Project sponsored by the Department of Environment, Government of India, New Delhi. The authors are thankful to the National MAB Committee -India- for the financial support, and to the Head of the Department of Zoology, University of Jodhpur, Jodhpur, for providing laboratory facilities.

References

Alam, M., 1980. Limnological studies of Sambhar salt lake and its reservoir. Ph.D. Thesis, University of Jodhpur, Jodhpur, India. 158 pp.

American Public Health Association, American Water Work Association & Water Pollution Control Federation, 1975. Standard methods for the examination of water and wastewater. 14th ed. APHA, AWWA, WPCF, Wash. D.C., 769 pp.

Baid, I. C., 1958. On the occurrence of *Artemia salina* in Sambhar Lake (Rajasthan). Curr. Sci. 27: 58–59.

Baid, I. C., 1962. Ecological studies on crustacean and insect fauna of the Sambhar Lake, Rajasthan with special reference to *Artemia salina* L. Ph.D. Thesis, University of Rajasthan.

Baid, I. C., 1969. The arthropod fauna of Sambhar salt lake, Rajasthan, India. Oikos 19(2): 292–303.

Bayly, I. A. E., 1969. Symposium on salt and brackish inland waters. Introductory comments. Verh. int. Ver. Limnol. 17: 419–420.

Bhargava, S. C., G. R. Jakher, M. M. Saxena & R. K. Sinha, 1987a. Ecology of *Artemia* in Didwana salt lake (India) p. 127–133. In: *Artemia* Research and its Applications. Vol. 3. Ecology, Culturing, Use in aquaculture. P. Sorgeloos, D. A. Bengtson, W. Decleir & E. Jaspers (eds.). Universa Press, Wetteren, Belgium, 556 pp.

Bhargava, S. C., G. R. Jakher, M. M. Saxena & R. K. Sinha, 1987b. Rearing *Artemia* in a salt pan near Sambhar Lake (India). In: *Artemia* research and applications. vol. 3: 271–274. Ecology, culturing, use in aquaculture. P. Sorgeloos, D. A. Bengtson, W. Decleir & E. Jaspers (eds.). Universa Press. Wetteren, Belgium, 556 pp.

Cole, G. A., 1979. Text book of Limnology. 2nd ed. C.V. Mosby Company, Missouri, USA. 426 pp.

Comín, F. A., M. Alonso, P. López & M. Comelles, 1983.

Limnology of Gallocanta Lake, Aragón, NE Spain. Hydrobiologia 105: 207–223.
Gessner, F., 1957. Van Golu zur limnologic des grossen soda sees in Ostanatolien (Turkei) Archiv. Hydrobiol. 53: 1–22.
Goldman, C. R. & A. J. Horne, 1983. Limnology. Tosho Printing Co. Ltd., Tokyo, Japan. 464 pp.
Hammer, U. T., J. S. Shamess & R. C. Haynes, 1983. The distribution and abundance of algae in saline lakes of Saskatchewan, Canada. In: Saline lakes. Proc. 2nd Int. Symp. Athalassic (Inland) saline lakes. U. T. Hammer (ed.). Dev. Hydrobiologia 16. Junk. The Hague: 1–26.
Haynes, R. C. & U. T. Hammer, 1978. The saline lakes of Saskatchewan. IV. Primary production by phytoplankton in selected saline ecosystems. Int. Revue ges. Hydrobiol. 63: 337–351.
Post, F. J., 1975. Life in the Great Salt Lake. Utah Sci. 36: 43–47.
Rawson, D. S. & J. E. Moore, 1944. The saline lakes of Saskatchewan. Can. J. Res. 22: 141–201.
Strickland, J. D. H. & T. R. Parsons, 1972. A practical hand book of seawater analysis. Bull. Fish. Res. Bd Can. 167, 310 pp.
Tiwari, K. K., 1958. Diagnosis of a new species of the genus *Branchinella* Saycee (Crustaceae, Brachiopoda, Anostraca) from Sambhar Lake, Rajasthan. J. Bombay Natl. Hist. Soc. 55: 585–588.
Topping, M. S. & G. G. E. Scudder, 1977. Some physical and chemical features of saline lakes in Central British Columbia. Syesis 10: 145–166.
Vareschi, E., 1982. The ecology of lake Nakuru (Kenya). III. Abiotic factors and primary production. Oecologia (Berlin) 55: 81–101.
Vollenweider, R. A. (ed.)., 1969. Primary production in aquatic environments. I.B.P. Handbook, 12: 213 pp.
Walker, K. F., 1973. Studies on saline lakes ecosystem. Aust. J. mar. Freshwat. Res. 24: 21–27.
Williams, W. D., 1964. A contribution to lake typology in Victoria, Australia. Verh. int. Ver. Limnol. 15: 158–163.
Williams, W. D., 1978. Limnology of Victorian salt lakes, Australia. Verh. int. Ver. Limnol. 20: 1165–1174.