Environmental Quality and Ecosystem
Stability: Vol IV-B, ENVIRONMENTAL QUALITY.
ISEEQS Pub. Eds.: E. Spanier, Y. Steinberger
and M. Luria; Jerusalem, ISRAEL, 1989

WATER QUALITY DYNAMICS IN THE SHALLOW LITTORAL OF LAKE KINNERET

SARIG GAFNY and AVITAL GASITH

George S. Wise Faculty of Life Sciences,
Institute for Nature Conservation Research,
Tel-Aviv University, Ramat-Aviv 69978, Israel

ABSTRACT

Annual water quality dynamics in the shallow littoral of Lake Kinneret was followed by monthly sampling at 1 m maximum depth during the period of August 1987 to September 1988. Excluding short-term events which could be related to allochthonous input with runoff or to algal bloom, the water quality of the shallow littoral remains relatively unchanged throughout the year. These events are detectable in the shallow water only, their timing and magnitude was site specific. This specificity may be attributed to the vicinity of the region to runoff sources and position relative to the dominant wind direction.

KEY WORDS: Littoral, Water quality, Lake Kinneret.

INTRODUCTION

Lake Kinneret is a warm monomictic lake situated in the northern part of the Jordan Rift Valley, about 200 m below sea level. The lake is a cryptodepression of tectonic origin. It is approximately 170 km^2 in surface area, with a relatively regular shoreline (shoreline development index of 1.16), 53 km in length. (Serruya, 1978). The maximum depth is about 48m (according to recent bathymetry, Berman pers. communic.) .

The littoral of the lake is characterized by the absence of submerged macrophytes, except for occasional, sporadic appearances in sheltered areas.

Based on the lower boundary of benthic algae (Dor, 1970), the littoral zone in Lake Kinneret extends to a depth of about 3 meters. The bottom substrate varies around the lake. It includes boulders and stones of various sizes consisting of basalt, limestone and flint. Finer substrate mainly composed of sand and silt is also found (Gasith and Gafny, in press). Lake level fluctuations periodically expose and inundate shore areas and influence the slope and substrate of the littoral region (Gasith and Gafny, in press).

Although Lake Kinneret is one of the better studied warm lakes (Serruya, 1978) there have been relatively few studies of the littoral none dealing with water quality aspects (e.g., Por, 1968; Por and Eitan, 1970; Dor, 1970)

The purpose of the present investigation is to study the dynamics of water quality in the shallow littoral zone around the lake in relation to the deeper littoral and the pelagial regions. This study is part of a larger project aimed at understanding the structure and function of the littoral of Lake Kinneret.

MATERIALS AND METHODS

Changes in water quality in the shallow littoral were followed monthly during the period of August 1987 to September 1988. During this period the lake level dropped from -210.5m to a minimum of -211m (in November) and increased to -208.85m (in May) followed by a decline to -209.2m. Samples were taken during the morning hours, at 1 m maximum depth, 30cm bellow the water surface, from 7 stations around the lake (Fig. 1). On two occasions, during the summer, samples were taken during the afternoon hours as well. The samples were collected directly into the sampling bottles. Water temperature, Secchi depth and wind conditions at the time of sampling were recorded.

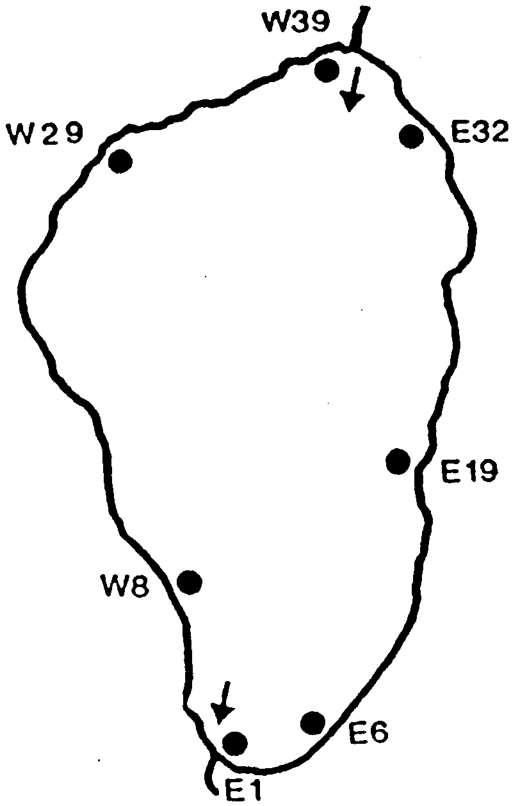

Fig. 1: Representative sampling stations in the shallow littoral of Lake Kinneret (arrows indicate inflow and outflow of the Jordan river).

The samples were transferred to the Kinneret Limnological Laboratory within two hours of sampling. The parameters and procedures of analyses were as follows:
ammonia - NH_4 (Solanzano, 1969), nitrate - NO_3 and nitrate - NO_2

(Strickland and Parsons, 1972), Kjeldahl nitrogen - TON (APHA, 1985), total phosphorus - TP, Soluble reactive phosphorus - DP (Strickland and Parsons, 1972), Salinity (APHA, 1985). Chloropyll-a content was determined fluorometrically on samples collected on GF/C filters and extracted with 90% acetone (Holm Hansen et al, 1965). Algae were identified and counted with an inverted microscope using Utermohl (1968) technique. Algal Biomass was calculated from measured cell volumes.

Water samples from the deep littoral (5-8m deep, within 100m of the shallow littoral) and from a station representing the pelagial (St. A, lake center) were collected on the same date and time by the staff of the Kinneret Limnological Laboratory (Berman et al., 1989). The data allows comparison of the dynamics of water quality characteristics of the shallow littoral with that of the deeper littoral and pelagial regions.

RESULTS AND DISCUSSION

Seasonal dynamics and spatial variability

A typical pattern of annual change of water quality in the shallow littoral of Lake Kinneret is demonstrated in the dynamics of suspended solids (Fig. 2). Excluding marked changes of short-term events, water quality of the shallow littoral remained relatively unchanged throughout the year. During these events, the values of most of the parameters varied within two orders of magnitude. The irregularities were recorded during March or April. They could be attributed to two major processes: a. An effect of allochthonous inputs observed at the end of winter (March, Fig. 3) and b. internal effects associated with algal blooms in April (Fig. 4).

The impact of these events differed among littoral regions around the lake. This is partly due to the fact that runoff and and inflow of flood water mostly restricted to the northern part of the lake, primarily by the Jordan River (Fig. 1). Correspondingly, northern littoral regions (represented by W29, W39, E32) were more affected by this process. It was reflected in parameters associated with particulate matter such as SS and TP (Fig. 3) as well as in Cl^-, a biologically conservative, dissolved parameter (Table 1). Chloride concentration in runoff water is an order of magnitude lower than in the lake thus allows tracing of the runoff current and its dilutions effect. (Table 1).

Table 1. Lowest chloride value in the shallow littoral (recorded in May).

STATION:	W39	W29	E32	W8	E19	E6	E1
CHLORIDE (mg/l):	160	179	189	190	192	192	196

The data suggest a positive correlation between the magnitude of the effect and the vicinity of the area to a major inflow source.

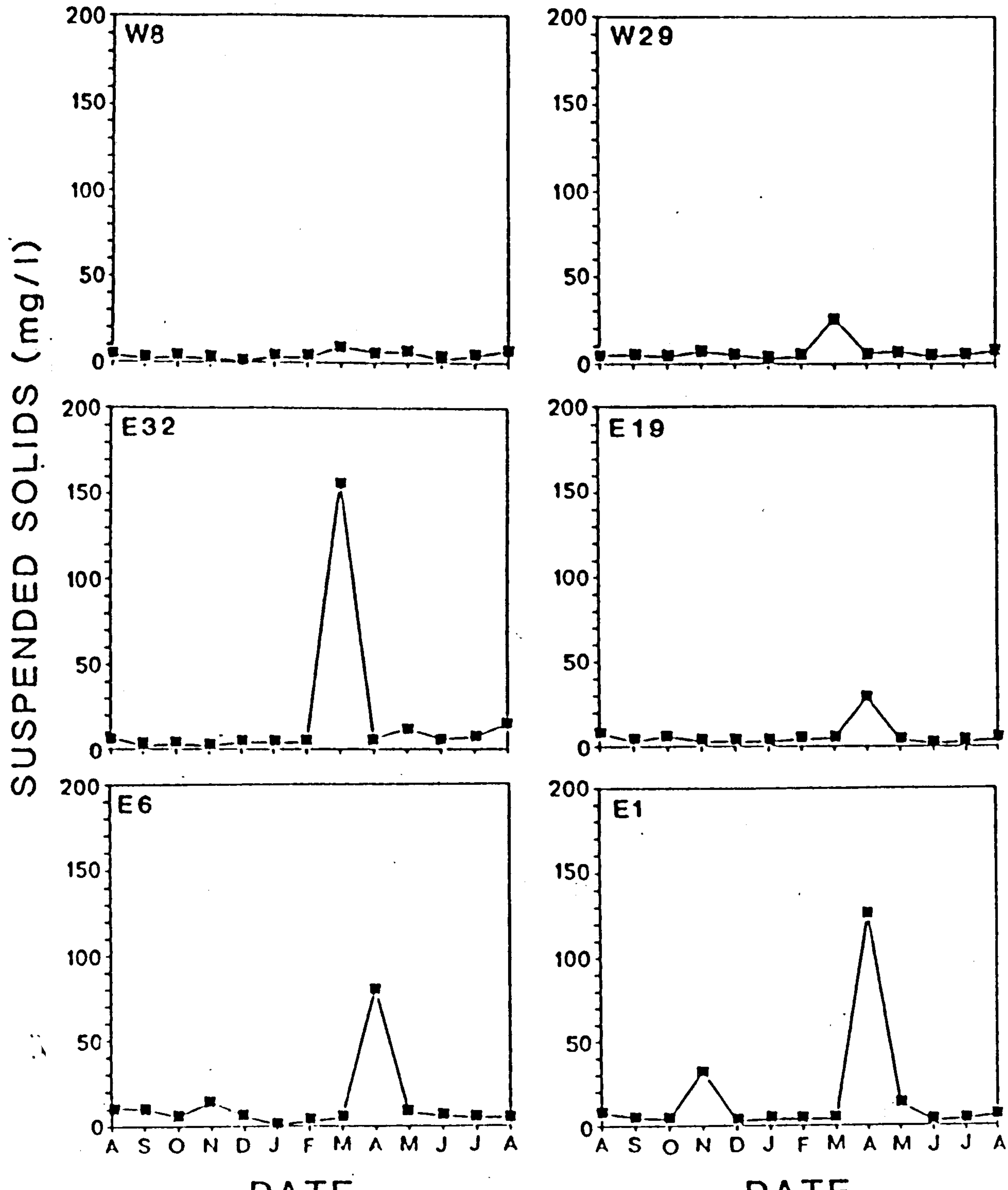

Fig 2: Seasonal dynamics of suspended solids in the shallow littoral of Lake Kinneret (station location is indicated in Fig. 1).

Indeed, the northeastern littoral region (W39) which was closest to the inflow of the Jordan River had the lowest Cl^- concentration and highest level of some other water quality parameters (Table 1, Fig.3). Berman et al., (1989) found similar effect for DP in 1987.

Littoral areas further to the south (E19, E6, E1, W8) were less affected by runoff (Table 1) and were more likely to be influenced by internal, lake processes. Phytoplankton dominate the production in Lake Kinneret (Berman and Pollingher, 1974) showing periodic

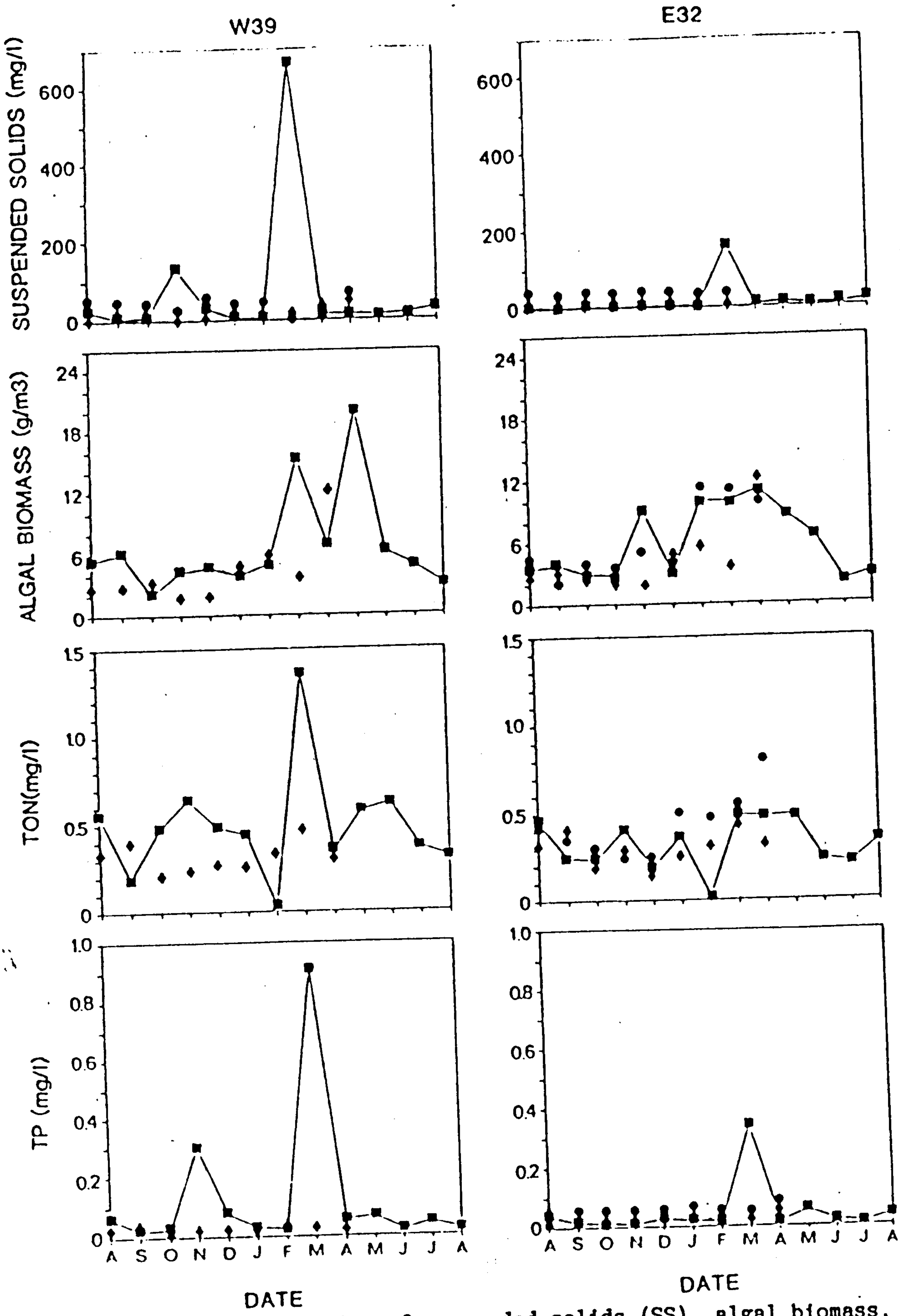

Fig. 3: Seasonal dynamics of suspended solids (SS), algal biomass, total organic nitrogen (TON) and total phosphorus (TP), in northern regions of the littoral of Lake Kinneret. Shallow littoral - squares, deep littoral - circles, Pelagial - diamonds.

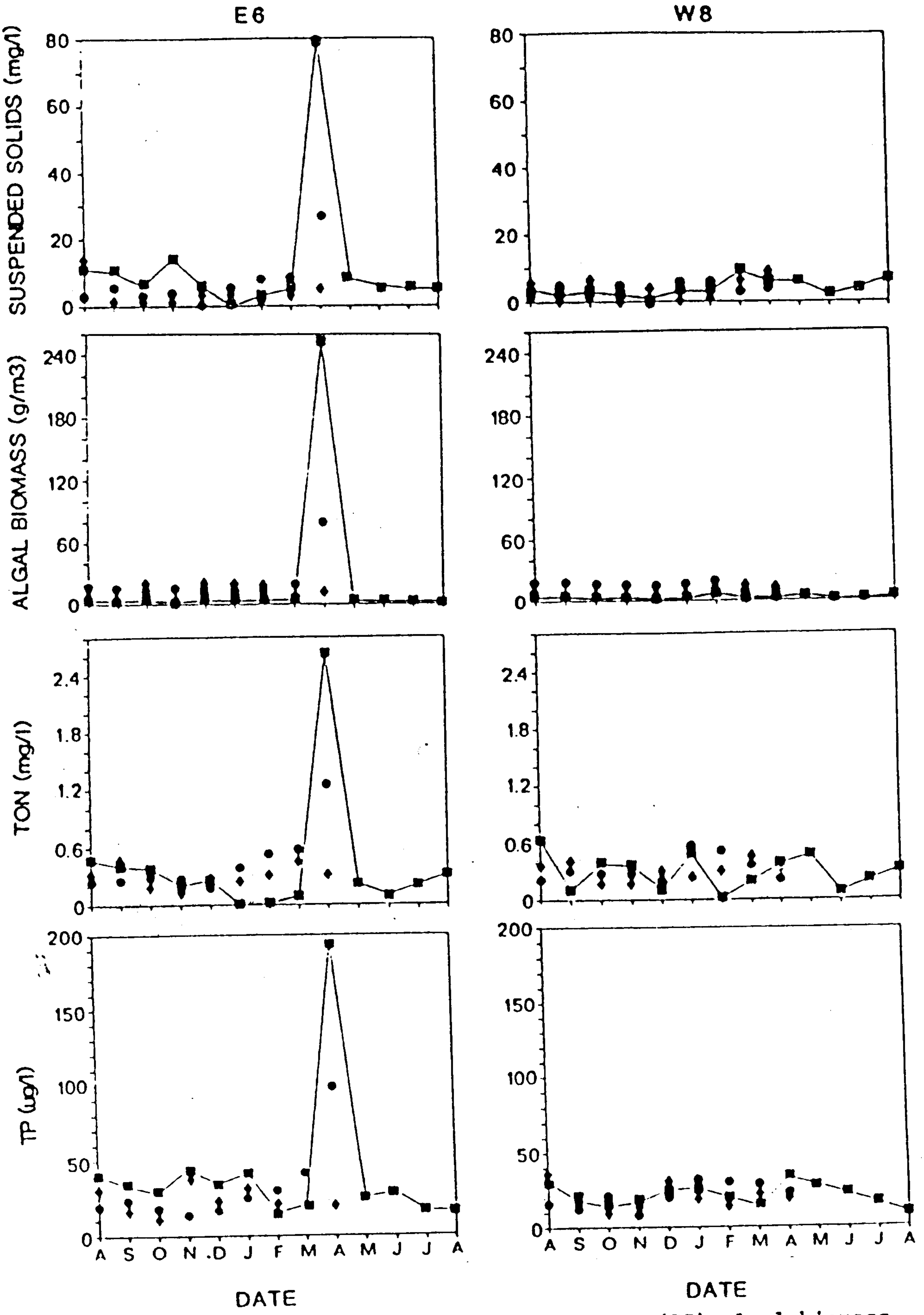

Fig. 4: Seasonal dynamics of, suspended solids (SS) algal biomass, total organic nitrogen (TON) and total phosphorus (TP) in southern regions of the littoral of Lake Kinneret. Shallow littoral - squares, deep littoral - circles, Pelagial - diamonds.

blooms usually of Peridinium. Our data indicated that the southeastern region of the lake (E1, E6), showed an increase in some parameters all related and coincident with a bloom of Peridinium, in April (25,600 mg/m^3, Fig. 4 and Table 1 in Berman et al., 1989). However, a difference was found between the water quality dynamics of southeastern and southwestern regions of the littoral. For example, the southwestern littoral region (W8) had consistently similar water quality throughout the year (Fig. 4). This west - east difference may be explained by the north-western afternoon winds which prevail in Lake Kinneret during late spring, summer and fall (Serruya, 1978) and are likely to concentrate the algae (during bloom time) leeward, i.e., in the southeastern region of the lake.

Diurnal variability

Preliminary observations on the short-term, diurnal variability in water quality in the shallow littoral during summer, revealed changes in water quality between morning and afternoon hours, mainly in eastern stations (Fig. 5). This may be attributed to the effect of the daily water turbulence generated by the north-western wind. The effect on the deeper littoral is yet unknown (Berman et al., 1989). The impact of this environmental disturbance on the littoral and on the littoral-pelagial interaction is yet to be investigated.

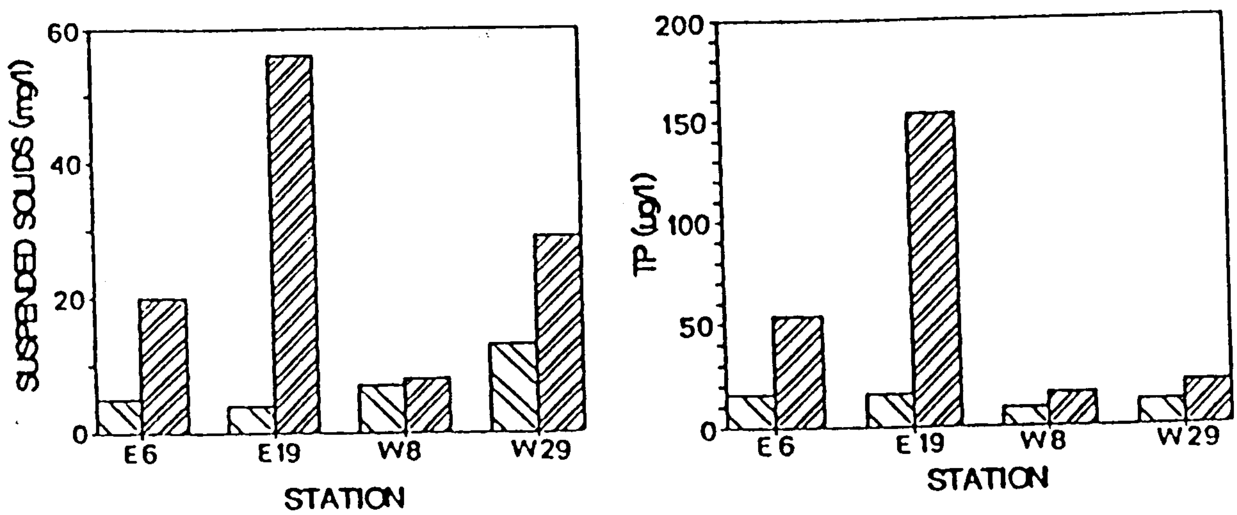

Fig. 5: Diurnal variability of suspended solids (SS) and total phosphorus (TP) in the shallow littoral in the morning (AM) and afternoon (PM) hours on 2.8.88.

Effect of depth

Short-term changes in water quality were observed in the shallow littoral (Figs 3 and 4) for events influenced by allochthonous inputs as well as that affected by an algal bloom. For the former, it was reflected for example by peaks in SS and TP. For the latter, peaks in TON, Chlorophyll-a and algal biomass were observed. This change in water quality dissipated deeper in the littoral within few tens of meters offshore. Dilutions in deeper water as well as wind generated resuspension and transport of algae and particulate matter to the littoral may be responsible for this difference in water quality dynamics between the shallow littoral and deeper regions of the lake.

Excluding short periods of irregularities, water quality in the shallow littoral was similar to that of the deeper littoral and the pelagial (Figs. 3 and 4). This was particularly apparent in regard to dissolved parameters such as NH_4 (Table 2), NO_3 and DP,

Table 2. Comparison of annual ammonia dynamics (μg/l) in the shallow littoral, deep littoral and pelagial of Lake Kinneret.

DATE	STATIONS												
	SHALLOW LITTORAL						DEEP LITTORAL						PELAGIAL
	W29	E32	E19	E6	E1	W8	W29	E32	E19	E6	E1	W8	A
1987													
11. 8	27	39	90	45	60	55	37	36	23	18	28	51	47
15. 9	1	10	15	3	4	13	4	8	8	22	4	7	7
27.10	24	22	19	19	18	29	21	26	19	15	17	21	29
17.11	103	109	155	104	77	147	64	88	99	80	110	85	62
29.12	197	209	237	199	195	255	210	219	241	198	188	226	236
1988													
12. 1	258	281	306	309	303	304	229	261	290	294	238	317	273
9. 2	10	11	11	7	31	12	1	2	1	2	5	3	17
9. 3	63	71	63	156	80	90	54	57	68	59	63	53	62
12. 4	40	26	27	31	31	31	23	25	24	23	31	25	27
10. 5	12	19	18	19	19	33	19	12	10	9	15	21	22
6. 6	25	23	23	39	49	42	132	34	25	45	60	56	24
5. 7	14	16	17	29	44	12	11	12	9	15	23	9	18
2. 8	21	28	28	40	47	22	15	20	20	15	15	15	12

the dynamics of which are primarily governed by processes within the lake.

It should be noted that only the southwestern region (W8) showed a consistent similarity to the deep littoral and the pelagial, throughout the year. This is probably associated with its greater distance from runoff sources as well as its windward position which reduces the effect of algal blooms.

During the reported period the lake level fluctuated about 2m. None of the water quality changes in the shallow littoral could be associated with this water fluctuation.

CONCLUSIONS

The dynamics of water quality in the shallow regions of the littoral of Lake Kinneret is characterized by short-term anomalies associated with transport of allochthonous materials and/or with algal blooms. These changes are less evident in the deeper littoral and the pelagial regions. The impact of these events in the littoral is site specific, being influenced by the vicinity to runoff sources or the position of the littoral region in regard to the dominant wind direction. Accordingly, there is a major north-south gradient in the change of runoff related water quality parameters and a northwest - southeast gradient of wind mediated effects.

Preliminary evidence exists for diurnal changes in water quality of the littoral on leeward regions as a result of daily, afternoon winds causing massive resuspension of bottom sediment in the shallow littoral, particularly in summer and fall. Other than wind generated resuspension, there is as yet no evidence for other littoral process which could significantly influence the magnitude and dynamics of water quality in this zone. Investigation should be directed to identify and quantify such processes. For example, can the rapid growth of periphyton (particularly in winter) function as a nutrient pump and influence the seasonal and/or diurnal nutrient dynamics in the shallow littoral. Possible direct and indirect influences of the bottom substrate on littoral water quality should not be overlooked.

ACKNOWLEDGEMENT

We wish to thank T. Berman, B. Kaplan and the staff of the Kinneret Limnological Laboratory for their kind assistance in sample processing and analysis and to U. Pollingher for providing phytoplankton data. This study was supported by a grant from the Israel Oceanographic and Limnological Research Ltd., and the Tel-Aviv University. Submitted in partial fulfillment of the requirements of Tel-Aviv University for a Ph.D. degree in zoology. A contribution from the Institute for Nature Conservation Research, George S. Wise Faculty of Life Sciences, Tel-Aviv University (INCR/6A/89).

REFERENCES

APHA, 1985. Standard methods for the examination of water and wastewater. American Public Health Association. 16th Ed 1268pp.

Berman, T., U. Pollingher, B. Kaplan and S. Chava. 1989. Limnological characteristics in shallow waters in Lake Kinneret, 1986-1989. (In this volume).

Berman, T. and U. Pollingher 1974. Annual and seasonal variation of phytoplankton chlorophyll and photosynthesis in Lake Kinneret. Limnol. Oceanogr. 19: 31-55.

Dor, I. 1970. Production rate of the periphyton in Lake Tiberias as measured by the glass-slide method. Isr. J. Bot. 19(1): 1-15.

Gasith, A. and Gafny S. 1989. Effect of water level fluctuation on the structure and function of the littoral zone in Lakes. In: M.M. Tilzer and C. Serruya (Eds.) Ecological structure and function in large lakes. Science-Tech Pub., Medison, Wisconsin. (In press).

Holm Hansen, O., C.J. Lorenzen, R.W. Holms and J.D.H. Strickland. 1965. Flourometric determination of chlorophyll. J. Cons. Int. Explor. Mer. 30: 3-15.

Por, F.D. 1968. The invertebrates zoobenthos of Lake Tiberias. I. Qualitative aspects. Isr. J. Zool. 17: 51-79.

Por, F.D. and G. Eitan. 1970. The invertebrates zoobenthos of Lake Tiberias. II. Quantitative data (level bottoms). Isr. J. Zool. 19: 125-134.

Serruya, C. 1978. Lake Kinneret Monographiae Biologicae. W. Junk Pub. The Hague. 501pp.

Serruya, S. 1978. Data concerning meteorological parameters measured on the lake or on the lake shores. (Solar radiation, air temperature, vapor pressure, barometric pressure and winds). In: Serruya, C. (Ed.) Lake Kinneret Monographiae Biologicae. W. Junk Pub. The Hague. p 59-69.

Solarzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol. Oceanogr. 14: 799-801

Strickland, J.D. and T. Parsons. 1972. A Practical handbook of seawater analysis, 2nd ed. Fish. Res. Bd. Can. 310 pp.

Utermohl, H. 1958. Zur vervollkommnung der quantitativen phytoplankton - methodik. Mitt. Int. Ver. Limnol. 9: 1-38.