Wat. Sci. Tech. Vol. 27, No. 7-8, pp. 363–371, 1993.

0273–1223/93 $24·00

EFFECT OF LOW WATER LEVEL ON THE WATER QUALITY OF THE LITTORAL ZONE IN 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

ABSTARCT

Water quality in the shallow littoral of Lake Kinneret was examined during a period of low water levels in 1989-1990. On calm days, no significant difference was found between the water quality on different sites around the lake or between the littoral and the open water. Lowering of the lake level in Lake Kinneret is associated with a major change in the nature of the bottom of the littoral zone in many sites, from rocky substrate in high lake levels (>212m below sea level) to sandy or clay in lower levels. During north-easterly storms, in winter, the concentrations of suspended solids and total phosphorus were markedly higher in leeward littoral sites compared to other regions of the littoral zone. This may be attributed to resuspension of sediments by the wave action over the soft bottom. In rainy winters, runoff, mainly Jordan River input, may locally affect the water quality and result in a north-south gradient.

KEY WORDS: Littoral, Water quality, Water level, Lake Kinneret.

INTRODUCTION

Effects of water level fluctuations on water quality in the littoral zone of lakes is variable (Osborne et al., 1987). Most of the studies reported a significant change in water quality mainly due to decomposition of decaying macrophytes, oxidation of organic substances and release of minerals from the sediments (e.g., Nees, 1964; Cooper 1966; Moss and Moss, 1969; McLachlan, 1970; Hestand et al., 1973; Osborne et al., 1987; Kurata, 1989). Drawdown may also increase shoreline erosion and thus enhance resuspension of bottom sediments in sites that are less exposed at higher lake levels (Grimas, 1962; Swanson, 1967; Geen, 1974; Barton and Carter, 1982; Clayton, 1982; Walker and Tyler, 1984; Mitchell and Rogers, 1985). Other studies reported no change in water quality following water level fluctuations (Sinclair, 1965, cited in Geen, 1974).

In an earlier paper (Gafny and Gasith, 1989) we described the water quality dynamics in the shallow littoral (<1m) of Lake Kinneret during a year of high water level (210.5 – 209m below sea level). Following relatively dry years, from 1989 to 1991 the lake level dropped from 209 to 213m below sea level (b.s.l.), and remained low (211.5 – 213m b.s.l.) for two years.

The objective of the present study was to evaluate the effect of low water level regime on the water quality in the littoral zone of Lake Kinneret.

MATERIALS AND METHODS

Water quality was examined during the period of November 1990 to February 1991. During this period the lake level varied from 212.95m to 212.05m b.s.l. Seven sites (2 western, 1 southern, 3 eastern and 1 northern, Fig. 1) were sampled six times over this period. Sampling was carried out during morning hours, at 1m maximum depth, 30cm below the water surface. On two occasions, the samples were taken when strong north-easterly winds prevailed. These winds caused high wave action especially in the south-western shores. The sampling procedure and analyses are described elsewhere (Gafny and Gasith, 1989).

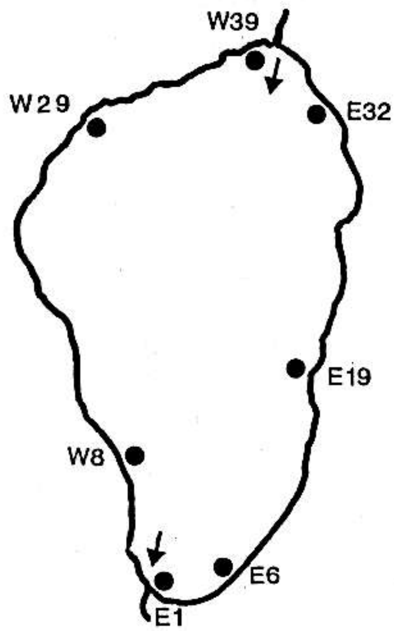

Fig. 1: Representative sampling stations in the shallow littoral of Lake Kinneret (arrows indicate inflow and outflow of the Jordan River).

RESULTS AND DISCUSSION

The nature of the littoral substrate around the lake and along perpendicular offshore transects changed dramatically as a result of water level fluctuations. Decline in the lake level from 209.5 to 213m b.s.l. has resulted in an increase in the proportion of sandy shores from 6 to 70%, respectively. Changes of the bottom substrate at the representative sites is shown in Table 1. Rocky substrate at high lake levels was replaced by soft sediments (sand, clay) at low lake levels.

Table 1: Comparison of the nature of the bottom substrate at high (209m b.s.l.) and low (213m b.s.l) lake levels at representative littoral sites around Lake Kinneret.

STATION	E1	E6	E19	E32	W39	W29	W8
209 b.s.l	STONES	CLAY	GRAVEL	STONES	SAND	STONES	STONES
213 b.s.l	CLAY	SAND	SAND	SAND	SAND	SAND	SAND

Comparison of selected water quality parameters in representative sites around the lake is summarized in Table 2.

Table 2: Selected water quality parameters (median and range) in representative littoral sites around Lake Kinneret.

	E1	E6	E19	E32	W8	W29	W39
pH	8.4 8.2-8.6	8.4 8.2-8.6	8.4 8.1-8.6	8.4 8.2-8.6	8.3 8.1-8.6	8.4 8.2-8. 6	8.3 7.5-8.7
SS 105° mg/l	7.4 2.8-19.3	5.2 2.4-6.1	3.8 2.1-4.1	4.2 2.8-4.9	4.6 2.7-8.1	5.4 2.6-6.4	4.4 .3-12.9
SS 550° mg/l	2.6 .5-11.1	2.5 .2-2.9	1.2 .001-1.5	1.3 .2-1.9	1.9 .3-5.2	2.1 .3-3.0	1.7 .001-3.2
TON mg/l	.49 .027-.50	.38 .015-.52	.36 .012-.39	.41 .015-.43	.42 .016-1.1	.40 .014-.46	.40 .026-.46
NH_4 mg/l	.151 .078-.36	.160 .057-.32	.157 .060-.27	.163 .066-.19	.156 .095-.28	.155 .095-.17	.141 .078-.92
NO_3 mg/l	.027 .012-.151	.046 .017-.142	.037 .011-.071	.028 .013-.049	.025 .021-056	.039 .022-.251	.052 .001-.147
NO_2 mg/l	.004 .002-.007	.003 .001-.011	.002 .001-.004	.005 .002-.007	.003 .001-.009	.004 .003-.008	.004 .001-.005
TP mg/l	.036 .016-.051	.019 .017-.022	.016 .012-.022	.016 .014-.018	.018 .016-.033	.018 .013-.020	.020 .015-.035
SRP mg/l	.009 .006-.015	.011 .004-.017	.008 .006-.008	.008 .005-.010	.008 .006-.015	.007 .005-.019	.011 .006-.014
Cl^- mg/l	242 240-250	242 242-246	240 240-244	243 240-242	242 237-244	241 247-243	239 222-244
Chl-a mg/l	5.60 3.80-8.00	4.44 3.60-8.00	5.03 3.60-6.50	3.85 1.80-8.90	5.00 4.14-8.90	7.10 3.60-8.90	7.40 4.50-7.70

A similar concentration of particulate matter, represented by suspended solids (SS) was measured in the different sites around the lake on calm days. An example is shown in Fig. 2a. The concentration of the SS during these days was similar to that measured during the same period in the open water (Berman, pers. comm.; Berman et al., 1989). The concentration of the dissolved parameters (e.g., SRP, TON, NH_4) did not show a consistent pattern of change among the sites.

On stormy days of north-easterly winds, which are typical in Lake Kinneret during winter, the concentration of the SS at the leeward sites more than doubled (St. E1, W8, Fig. 2b). A similar increase was measured also in the concentration of the total phosphorus (e.g. TP >0.048 mg/l in the leeward site, E1, compared to <0.02 mg/l in the other sites). The dissolved parameters showed no such change (e.g. SRP, Fig. 3).

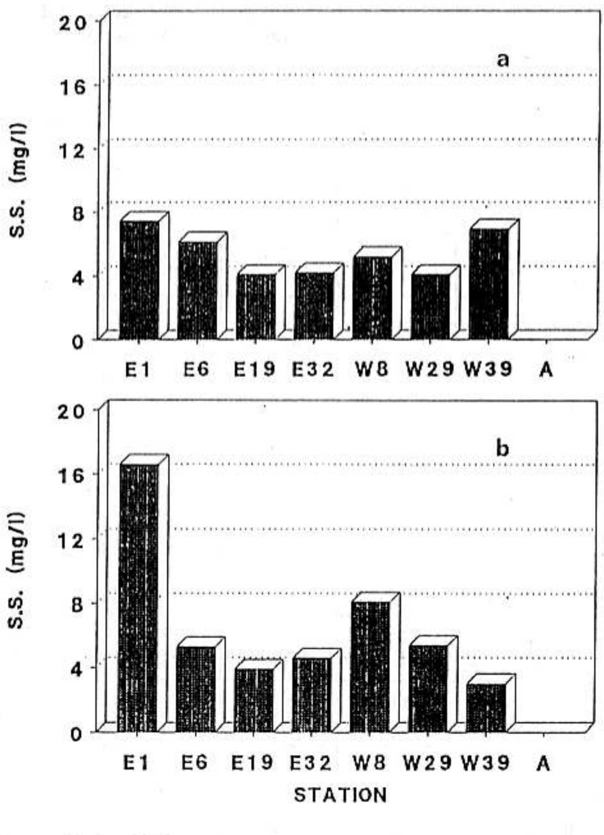

Fig. 2: Suspended solids variation in representative littoral sites around Lake Kinneret. (a: calm day, December 25th 1990, b: north-easterly storm, January 1st 1991). Station A is a mid-lake control site.

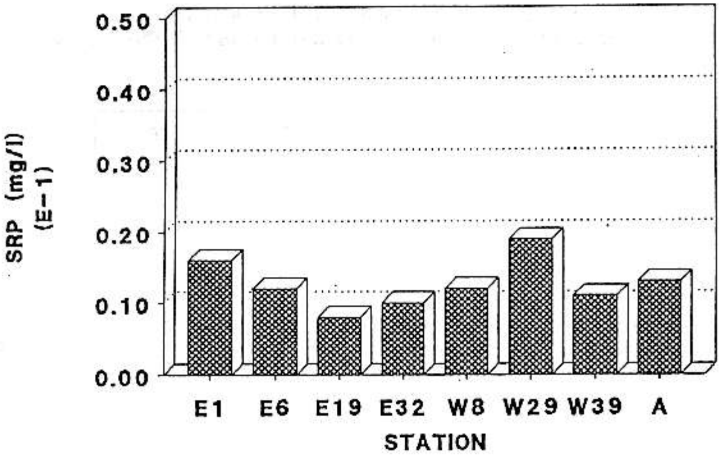

Fig. 3: Soluble reactive phosphorus concentration in representative littoral sites around Lake Kinneret during a north-easterly storm (January 1st, 1991).

Wave action and water movements are among the most significant factors affecting the water quality in the shallow regions of lakes (Hutchinson, 1975; Barton and Carter, 1982), especially during storms (Twinch and Peters, 1984). The effect of the wave action in lakes is usually limited to the shallow littoral and decreases with depth (Barton and Carter, 1982; Carper and Bachmann, 1984; Twinch and Peters, 1984; Barton, 1986). Strong effect of wave action as reflected by an increase of the suspended solids concentration was reported, for example, in the littoral zone of Lake Michigan (Chambers and Eadie, 1981). This effect was not detected in the deeper parts of the lake (Eadie et al., 1984). Barton and Hynes (1978) reported an effect of wave action on water quality at leeward sites of the shallow littoral of Lake Erie.

A significant positive correlation was found between the SS and the TP concentrations in Lake Kinneret (Table 3). The correlation coefficients between the SS, and chlorophyll-a and with dissolved parameters such as SRP and Nitrate were low and not significant (Table 3). Accordingly, the increase in SS is associated with resuspension of bottom sediment and not with algal cells. Release of dissolved nutrients from interstitial waters would be difficult to detect due to a dilution effect.

A similar water quality was recorded in the littoral zone in winters of high (1987/88) and low (1990/91) lake levels except for periods of short-term events. Higher concentrations of particulate matter were locally recorded in

Table 3: Correlation coefficient (r) and level of significance (p) between the concentration of suspended solids and of Chlorophyll-a, NO_3, SRP and TP (n=35).

	Chl-a	NO_3	SRP	TP
r	0.26	0.31	0.39	0.80
p	>0.1	>0.1	>0.1	0.001

the littoral zone at high lake levels mainly following runoff events, as a result of transport of allochthonous material (Gafny and Gasith, 1989). At low lake levels, high concentrations of particulate matter were only detected following strong winds, at leeward sites. This may be attributed to the effect of strong wave action over soft sediments which characterize most of the littoral bottom at low lake levels. A similar wind effect was detected at high lake levels (1987/88) in summer, a period of strong, daily north-west winds. In this case, resuspension of bottom sediments was most apparent on eastern sites which consist mostly of soft sediment (Gafny and Gasith, 1989; Gasith and Gafny, 1990).

Winter inputs from the Jordan River and other streams may locally affect the concentration of dissolved compounds. This was evidenced for example in a lower chloride concentration recorded at the northern site (W39) and at the north-western shore (W29) during the rainy winter of 1987/88. Such effect was not detected during the dry winter of 1990/91 (Table 4).

Table 4: Chloride concentration (mg/l) measured on March 12, 1988 (rainy winter) and February 19, 1991 (dry winter) in representative littoral sites around Lake Kinneret.

STATION	E1	E6	E19	E32	W39	W29	W8
March/88	202	205	202	205	174	195	200
Febr./91	238	239	239	237	234	236	238

The effect of allochthonous inputs or wave action can be demonstrated also by a multivariate hierarchical classification of the water quality in the different sites at different lake levels (average cluster analysis, Krebs, 1989). Figure 4a shows that, for example, on 27.12.87, the northern site in the vicinity of the inflow of the Jordan River (W39) differed from all other stations (Euclidic distance, 0.71). The other stations showed relatively small differences in water quality (Euclidic distance <0.3). During the winter of 1990/91 (low lake levels) the water quality in the northern site (W39) was similar to that of most other stations (Fig. 4b). On days of north-western winds the water quality in the southern region (e.g., E1, 25.12.90) differed from that of all other stations (Euclidic distance >6, among other stations <2, Fig. 4b).

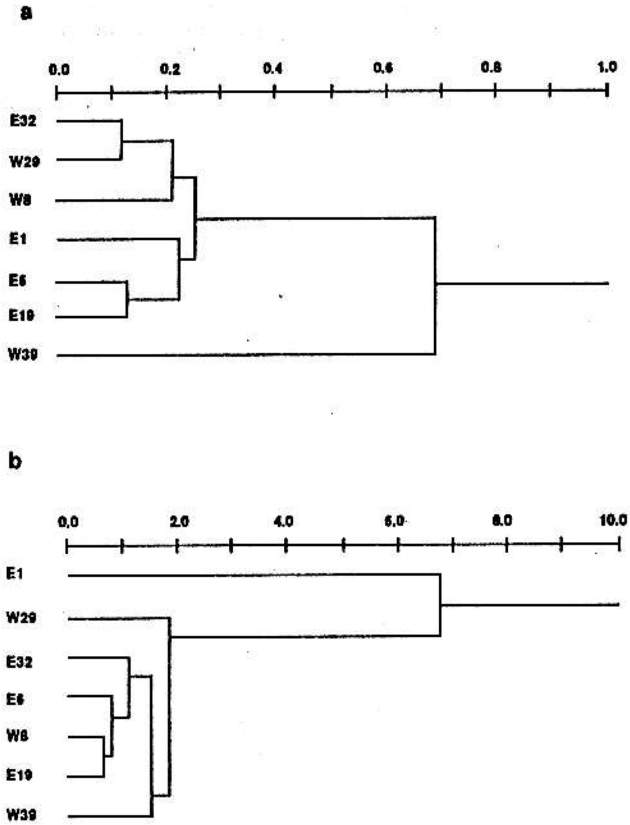

Fig. 4: Examples of cluster analysis of water quality in seven representative littoral sites around Lake Kinneret. a - 29.12.87, (runoff input). b - 25.12.90 (north-westerly wind).

CONCLUSIONS

Similar water quality was found in the shallow littoral around Lake Kinneret at high (1987/88) or low (1990/91) lake levels in winter except for certain regions which are locally affected by short-term events such as runoff or strong winds). Runoff, mainly Jordan River inputs, locally affect littoral sites in rainy winter and could result in a detectable north-south gradient of water quality. The extent of the wind effect may change as a function of the lake level. Wind driven resuspension may influence the water quality in leeward littoral sites particularly during low lake levels. This is probably associated with the increase in littoral areas of soft sediments as a result of the decline in the lake level.

At maximum lake level (ca 209 b.s.l.) wave attack causing shore erosion is expected to affect water quality in the shallow littoral. Some effect on water quality may also be expected as a result of inundation of vegetation which has developed on the exposed shores during periods of low lake levels. Earlier estimate of the vegetative biomass suggests only minor effect on the concentration of the organic matter in the lake compared to the contribution from algal production and allochthonous inputs (Gasith and Gafny, 1990). These aspects should be further investigated.

ACKNOWLEDGEMENT

We wish to thank T. Berman, B. Kaplan and the staff of the Kinneret Limnological Laboratory, Y. Geifman and the staff of the Mekoroth Water Quality Analysis for their kind assistance in the analysis of the water samples. This study was supported by a grant from the Water Commission.

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