Monitoring and managing lake Kinneret and its watershed, Northern Israel, a response to environmental, anthropogenic and political constraints

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MONITORING AND MANAGING LAKE KINNERET AND ITS WATERSHED, NORTHERN ISRAEL, A RESPONSE TO ENVIRONMENTAL, ANTHROPOGENIC AND POLITICAL CONSTRAINTS

D. Markel*
* Lake Kinneret & Watershed Monitoring Dept., Israeli Water Commission, Ministry of National Infrastructure, State of Israel. E-mail: dmarkel@int.gov.il

SUMMARY – Lake Kinneret is the only large water surface source in Israel, with an area of 167 km^2 it supplies some 30% of the country's freshwater. The watershed of the lake is 2730 km^2 in area, and is intensively used for agriculture and tourism purposes. The pollution from the watershed and the necessity of pumping water from the lake are threatening the water quality of the lake. Monitoring water quantities and qualities in the lake and its watershed provides the basis for current operation and for decision making in planning management of the watershed, the lake, and proposed engineering projects. Since 1999 some structural, technical and logistical changes were introduced into the monitoring-management systems. These changes led to a lake-watershed integrated monitoring system with synoptic and continuously measurements operation. In the current work the above system will be described including the physical setting, the structure of the monitoring system and the way in which it has been operated and developed, mainly in the last 5 years. The Monitoring Task Force, set up by the Water Commissioner in 1998, coordinates the monitoring work of all organizations and guides improvements of the monitoring system, by introducing new sampling and analysis techniques. A series of management activities in the watershed were carried out in order to reduce nutrient load from the watershed to the lake. The innovations presented in the current work are part of the efforts to monitor, researching and manage Lake Kinneret and its Watershed according to environmental, anthropogenic and political constrains.

Keywords: lake Kinneret, watershed, monitoring, management, lake level, salinity, eutrophication

1. INTRODUCTION

Lake Kinneret is the only freshwater lake in Israel, from which about 30% of the country's potable water is supplied. The lake also sustains a large private and commercial fishery with an annual yield of 2000 tons (http://marine.ocean.org.il/about.html). In addition, the lake is a prime tourist attraction, as well as a religious site. Since 1964, when the National Carrier began transferring water from Lake Kinneret to the centre and south of the country, water supply for urban and agricultural consumers has become the main role of the lake. The lake and its basin supplies on average ca. 550 MCM annually, of which about 400 MCM are pumped through the National Water Carrier to the centre of the country and 100 MCM are supplied directly to consumers around the lake. In addition, 55 MCM are supplied annually to the Hashemite Kingdom of Jordan. Maintaining and improving water quality in Lake Kinneret are therefore a major national and regional concern.

The area of Lake Kinneret is approximately 167 km^2, changing somewhat with water level. The watershed area is 2730 km^2, of which 2070 km^2 are in Israel and the rest in Lebanon (Fig. 1). The watershed is bordered in the north by the basin of the Litany River and the Hermon Mountain, the Golan Heights in the east, and Galilee in the west (Fig.1). The major water inflow to the lake is the Jordan River (Fig. 1), which drains the relatively high-rainfall region of the Upper Galilee and the Golan Heights. In addition, there are several smaller streams such as Meshushim Stream, which drains the Golan Heights, and Amud Stream, which drains the carbonate Eastern Galilee. Some 200,000 people live in the Israeli part of the watershed, under 6 regional authorities, and 25 local and municipal authorities. About 2-3 million tourists visit Lake Kinneret and its watershed annually, which adds significant anthropogenic pollution. The area of the watershed is used primarily for agriculture: orchards, field crops, fishponds, cowsheds, and cattle-grazing areas. This determines the main pollutants in the watershed: nutrients, herbicides, pesticides, and pathogenic bacteria (Berman 1998).

Industrial areas in the basin are few and small; hence they produce only a small fraction of the pollution that enters the lake from its basin.

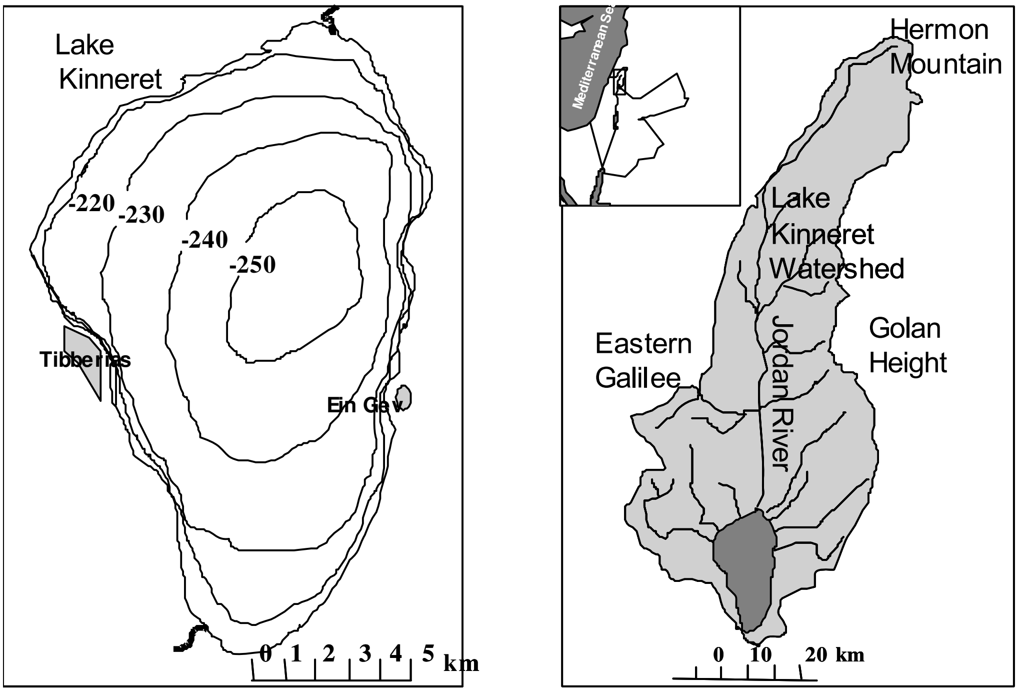

Figure 1. Left: Bathimetric map of Lake Kinneret; Right: Location map of Lake Kinneret and its watershed

The water law in Israel determines that the water commissioner is responsible for preserving and managing the water resources of the nation. These are mainly Lake Kinneret and the two major aquifers - the Mountain Aquifer and the Coastal Aquifer. In the 1990s pumping from the aquifers and Lake Kinneret has exceeded the average replenishment, which has resulted in declining water levels in the aquifers and the lake. This consequence led to a debate regarding the future impact of lake level drop on its water quality. The source of this debate was the necessity to increase the lake operational inventory and prevention of overflowing water to the southern Jordan River. On the other hand lowering the lake level could lead to several negative impacts on the lake water quality in particularly in two main subjects: salinity and stability of the ecological system of the lake. Indeed, the lake level dropped since 1995 to 2001 and reached a minimum of -214.87 m ASL, the lowest level in the known history of hundreds of years (Gal & Markel 2000). Fortunately, the rainy winter of 2002-2003 increased the lake level with in 4.7 meters (Fig. 2) and prevented a continuous crisis. However, the heavy rain superimposed with drainage works conducted in the watershed between 1995 and 2000 resulted in enhanced erosion and an increase in sediment removal and transfer during 2003 (Markel 2004).

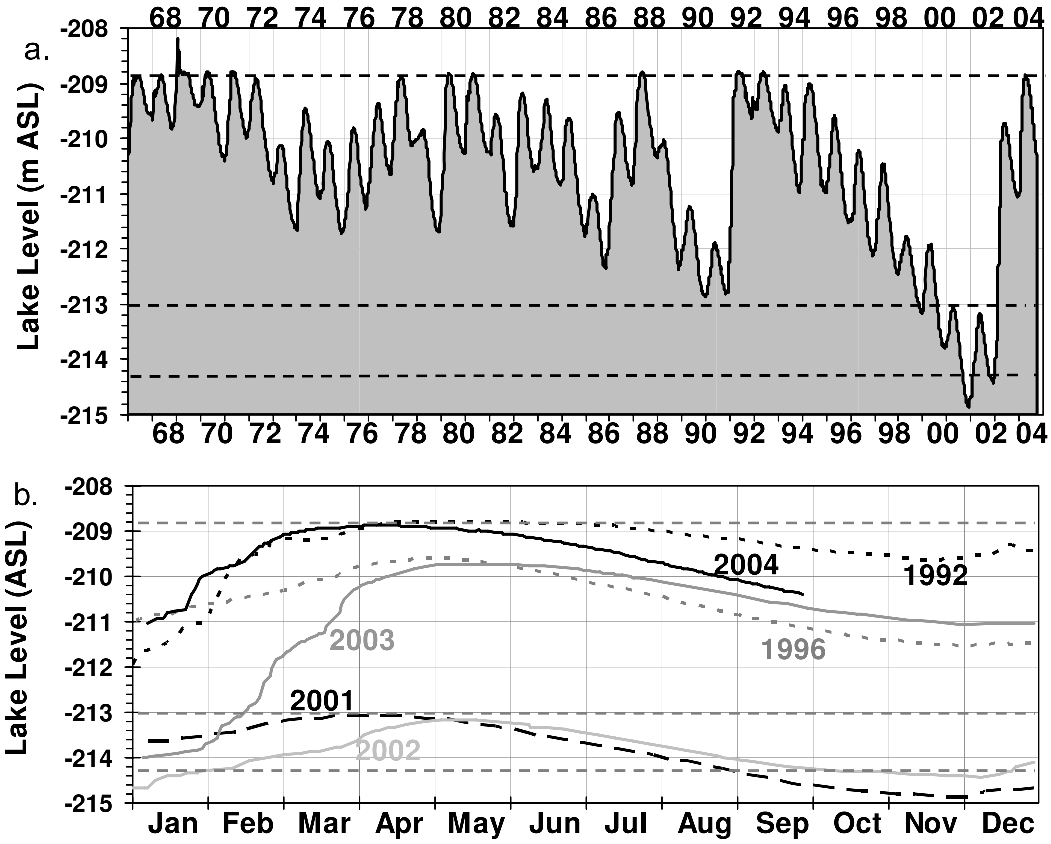

Figure 2. a. Water levels of Lake Kinneret 1966-2001. b. Seasonal changes in Lake Kinneret level 1992, 1996, 2001-2004. (Source: Israel Hydrological Service). In both figures the maximum and minimum operational levels are marked by horizontal dashed lines.

The large increase in human activities in the drainage basin over the past 50 years has led to the appearance of various diffuse sources of pollutants, including agricultural, industrial, and anthropogenic sewage sources. Superimposed on these were the drainage of swamps in the Hula Valley and the diversion of the Jordan River from its historical route through the 1950s. Since 1994 there has been a noticeable change in water quality in Lake Kinneret, mainly regarding the population of algae (Berman 1996b). It is reasonable that these changes are related to the increased input of pollutants from the watershed and the changes in water level. Accordingly, concern for water quality in the lake has led to the creation of an extensive water quantity and quality monitoring system, initiated in 1967. In accordance, a supervision system (Lake Kinneret Authority) was founded in order to supervise, the main pollution contributors. A series of management activities in the watershed were carried out in order to reduce nutrient load from the watershed to the lake. The innovations presented in the current work are part of the efforts to monitor, researching and manage Lake Kinneret and its Watershed according to environmental, anthropogenic and political constrains.

2. THE ORGANIZATIONAL SETUP

The responsibility for managing Lake Kinneret resides with the Water Commissioner, the senior government official in charge of water in the country. The Water Commission belongs to the Ministry of National Infrastructure, but it is also guided by instructions from a number of other Ministries. Mekorot Water Company is responsible for the supply from the lake, through the National Water Carrier to the south of the country, and by several local water systems to consumers in and around the watershed. The organizations involved in monitoring and managing Lake Kinneret and its watershed and their roles and responsibilities are (Fig. 3):

- Hydrologic Service – flows in the watershed and lake water levels.

- Alon Laboratory of the National Oceanographic and Limnologic Organization (KLL) – chemical and biological water quality in the lake.
- Mekorot Kinneret Watershed Unit - water quality in the watershed's waterways, and volume, salinity and energy -balance in the lake.
- MIGAL - a private regional research institute and laboratory – herbicides, pesticides and organic contamination in the watershed.
- The Kinneret Authority – supervision over activities in the watershed, around, on and in the lake.
- The Kinneret Lake and Watershed Monitoring Task Force – appointed by the Water Commissioner to coordinate and supervise the monitoring and analysis activities of the other bodies, and assist in converting the findings into operational decisions by the Water Commissioner.

The Water Commissioner set up the Monitoring Task Force in 1998, following several reports critical of the monitoring situation, to coordinate and guide the work of all organizations. The task force responsibilities are:

- To create a mechanism for planning, operating, analyzing, and reporting of the monitoring results.
- To secure integration and coordination among all organizations and components of the monitoring system.
- To guide improvement of the monitoring system, by introducing new sampling and analysis techniques, and to optimize the number, location and frequency of the sampling stations, and the parameters monitored.
- To improve the process of interpretation, reporting and advice to the decision-makers.
- To evaluate the utility of proposed new models for simulating lake and watershed processes, designed to aid decision-making with respect to planning and management alternatives in the watershed and the lake.

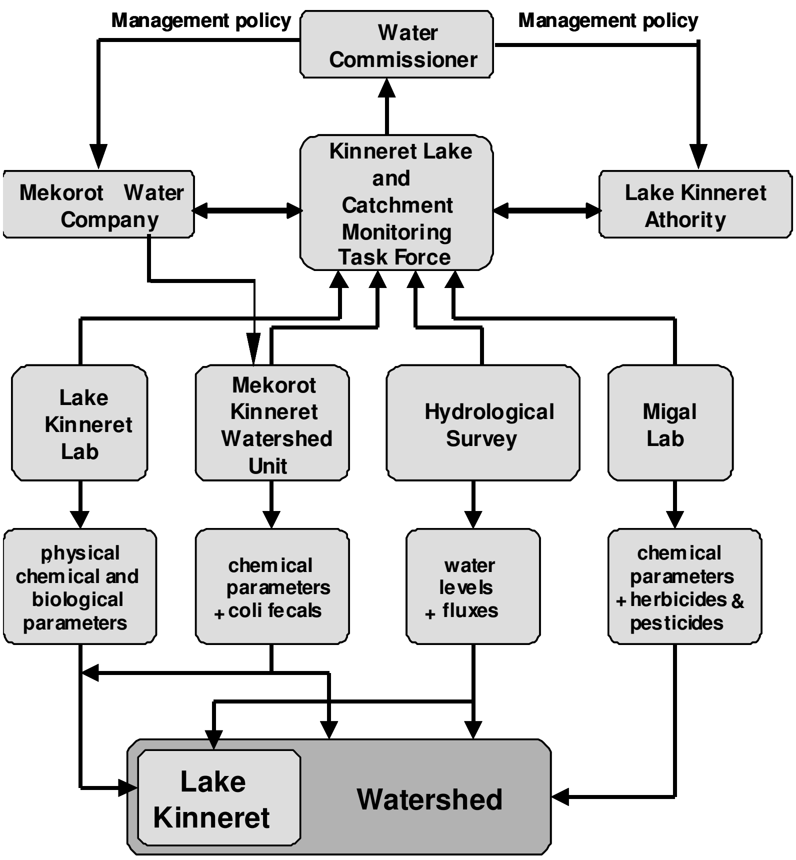

Figure 3. Organizational structure of Lake Kinneret and its watershed monitoring and management systems.

3 THE MONITORING SYSTEM

The location of the monitoring stations in the lake and watershed are shown in Fig. 4. There are five stations in the lake (denoted by letters). Station A is at the deepest point (about 44 meters), while the others span a range of depths (10 – 20 m) and conditions. Station A is the most intensively monitored and analyzed, and it has been found that its data are indeed the most representative of conditions throughout the lake, except in the littoral (Serruya 1978, Gafny & Gasith 1993). There are 14 monitoring stations in the watershed, where 6 of them are located in the upper Jordan River catchment and the other are located near the streams inlets to the lake (Fig. 4).

The chemical parameters and frequency of measurements in the watershed and the lake are shown in Table 1. Most of the parameters are measured weekly at five stations at several depths. Thus, the measurement system in Lake Kinneret is one of the most detailed in the world. For example, Lake Tahoe, California, an important ultra-oligotrophic and large lake (with an area of 500 km^2 and average depth of 313 m), is monitored by sampling 13 depths at a single station once every 10 days (Goldman 1988).

In the watershed daily load of nitrogen, phosphorus and total suspended solids is evaluated by multiplying the daily water volume with the specific chemical concentration. These loads are used to trace the impact of natural and management changes in the watershed on the transportation of point source and non point source pollution to the downstream lake.

Table 1. Chemical, biological, and physical parameters measured by the monitoring system of Lake Kinneret and its watershed

Symbol	Parameter	Frequency in the Lake	Frequency in the Basin
	Chemical parameters		
Cl^-	Chloride	Weekly	Daily/weekly (*)
Alk	Alkalinity	Bi-weekly	Daily/weekly
SO_4^{2-}	Sulfate	Bi-weekly	Daily/weekly
Na^+	Sodium	n.m. (**)	Daily/weekly
K^+	Potassium	n.m.	Daily/weekly
Mg^{2+}	Magnesium	n.m.	Daily/weekly
Ca^{2+}	Calcium	Bi-weekly	Daily/weekly
DIC	Dissolved inorganic carbon	Bi-weekly	n.m.
TOC	Total organic carbon	Bi-weekly	n.m.
H_2S	Sulfide	Bi-weekly	n.m.
SiO_2	Silicate	Bi-weekly	Daily/weekly
NO_3^-	Nitrate	Weekly	Daily/weekly
NO_2^-	Nitrite	Weekly	n.m.
NH_4^+	Ammonium	Weekly	Daily/weekly
DKN	Dissolved kjeldahl nitrogen	Weekly	Daily/weekly
TKN	Total kjeldahl nitrogen	Weekly	Daily/weekly
TON	Total organic nitrogen	Weekly	Daily/weekly
TN	Total nitrogen	Weekly	Daily/weekly
DP, SRP	Dissolved phosphorus (orthophosphate)	Weekly	Daily/weekly
TDP	Total dissolved phosphorus	Weekly	Daily/weekly
TP	Total phosphorus	Weekly	Daily/weekly
TSS	Total suspended solids	Weekly	Daily/weekly
Turb	Turbidity	Weekly	Daily/weekly
PH	PH	Weekly	Daily/weekly
DO	Dissolved oxygen	Weekly	n.m.
Cond	Electrical conductivity	nm	Daily/weekly
	Biological parameters		
Coli F.	Coli fecal	Monthly	Daily/weekly
Chlrph.	Chlorophyll A	Biweekly	n.m.
P.P.	Primary production	Biweekly	n.m.
Phyto	Phytoplankton (biomass and species)	Biweekly	n.m.

Symbol	Parameter	Frequency in the Lake	Frequency in the Basin
Zoo	Zooplankton	Biweekly	n.m.
Fish	Total fish biomass	Bimonthly	n.m.
	Physical parameters		
Temp	Water temperature	Weekly	Daily/weekly
Seki	Seki depth	Weekly	n.m.
LP	Light penetration	Biweekly	n.m.
AT	Air temperature	10 minutes	n.m.
SWT	Surface water temperature	10 minutes	n.m.
RH	Relative humidity	10 minutes	n.m.
LI	Light intensity	Hourly	n.m.

(*) Daily/weekly means that in some of the basin stations the parameter is measured daily and in some weekly.
(**) n.m. the parameter is not measured in the lake or the watershed.

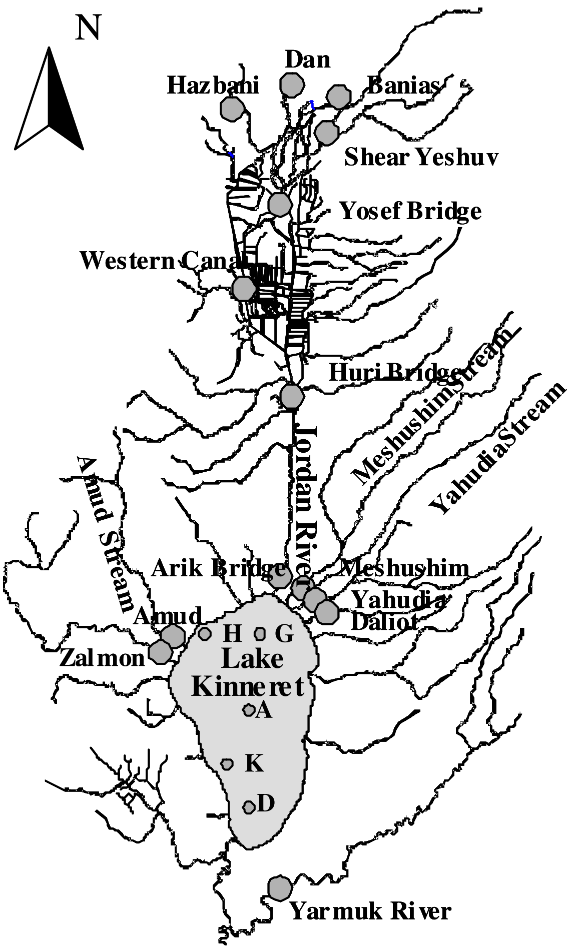

Figure 4. Location map of monitoring stations in Lake Kinneret and its watershed

3.1. Improving the monitoring

Since its initiating in 1998, the monitoring task force promoted the monitoring system towards the incorporation of synoptic and continuous monitoring approach (Markel & Shamir, 2002). The spatial approach was partially implemented by the introduction of a Mini Bat, which is a towed vehicle carrying instruments for spatial monitoring. The Mini Bat carries a set of electrodes and other measurement tools to measure conductivity, temperature, turbidity, and chlorophyll while TSS concentration will be measured in the future (Markel 2002). The next step towards spatial monitoring will be the implementation of remote sensing techniques. A satellite image usage for monitoring the chlorophyll, temperature and TSS in the lake as well as creating land use maps in the watershed is already in development. In order to achieve a continuous monitoring, an eco-raft was introduced to station A on May 2002. This eco-raft is equipped with a profiling unit (RUSS, Apprise Technologies), to which a YSI multi-sensor package is attached. This system is capable of automatically *in-situ* monitoring of depth, temperature, conductivity, turbidity, chlorophyll, dissolved oxygen and pH, at pre-programmed time and depth intervals. Data collected by the RUSS profiling unit are stored on a computer on the raft and are sent in real time by radio telemetry to a computer at the Kinneret Lab (Zohary & Gal 2002). For example, it is shown in Figure 5 that by conducting continuous vertical profile of chlorophyll one can detect the daily migration of *Peridinium*, the most common algae in Lake Kinneret, which was well known but couldn't be recorded before.

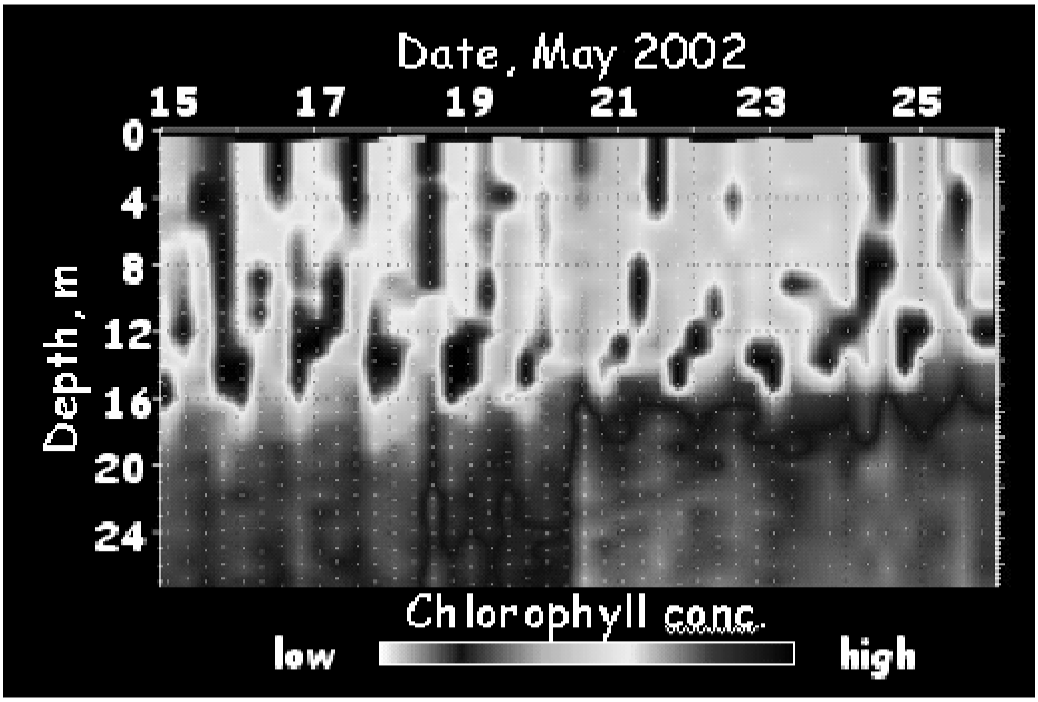

Figure 5. Chlorophyll concentration in vertical profiles measured in situ by the eco-raft in station A, Lake Kinneret, after Zohary & Gal 2002

Except of the above projects, the monitoring task force initiated a set of projects in order to improve the monitoring, notably:

- Publishing an integrated report for the state of the lake and its watershed (Kolodny *et al*. 2000). The fragmented approach to the lake and its watershed has been a main criticism regarding the monitoring system.
- An intercalibration project among 30 labs in Israel, as a quality assurance test of the labs involved in the monitoring effort. The project was led by the Geological Survey of Israel and Mekorot Company's central laboratory.
- A program for monitoring Cyanobacteria and their products led by KLL and financed by the Water Commission.
- Increasing the number of sampling stations for algae and their dynamic activity - from one single station to eight, with three of them on the shores of the lake.
- Monitoring of heavy metals - Fe, Mn, Al, Cu, Cd, Pb, Cr, Mo, Zn, U, and a few others.
- Introduction of a new method for measuring the primary production by $\delta^{18}O$ of the dissolved oxygen in the waterbody (Luz & Barkan 2000).
- Measuring the concentration of the protozoa *Giardia* and *Cryptosporidium* in the lake and some of the streams.

- Quantifying the amount of phosphorus enter the lake from airborne particles (dust).
- Quantifying the amount of phosphorus and nitrogen that is emitted from the trout ranches in the north part of the watershed.

4. WATER QUALITY

Physical, chemical, and biological qualities of the water in the lake are the result of a complex set of physical, chemical, and biological processes and interactions. Space here does not allow elaboration, and the interested reader is referred to the extensive literature of reports and scientific papers published regularly (Assouline 1993; Berman 1996a,b, 1998; Gophen *et al*. 1990; Walline *et al*. 1993). Other references (some in Hebrew) can be found in the data-base of the Grand Water Research Institute (http://wri.technion.ac.il/cgi-bin/abstract.html).

A main question regarding the water quality of Lake Kinneret is how to characterize and present it, since there are a large number of parameters. There are several ways to present water quality of a lake, most of them based on the concentrations of important parameters (such as: PO_4^{-3}, NO_3^-, Cl^-, turbidity, BOD, chlorophyll, chlorophyll, E. Coli, and Cyanobacteria), their change over time, and their relation to a defined range of values. A similar method has been developed by Hambright *et al*. (2000) for Lake Kinneret and is shown in Figure 6. It is suggested that water quality of Lake Kinneret deteriorated in the mean of increasing salinity and cyanobacteria ratio to total algal biomass (Fig. 6**).** One of the main threats on Lake Kinneret water quality is the increasing concentration of cyanobacteria, mainly *Microcistic* and *Aphanizomenon*. These algae are usually phosphorus limited; hence, reducing phosphorus loads from the watershed is a major task of the integrated lake-water management.

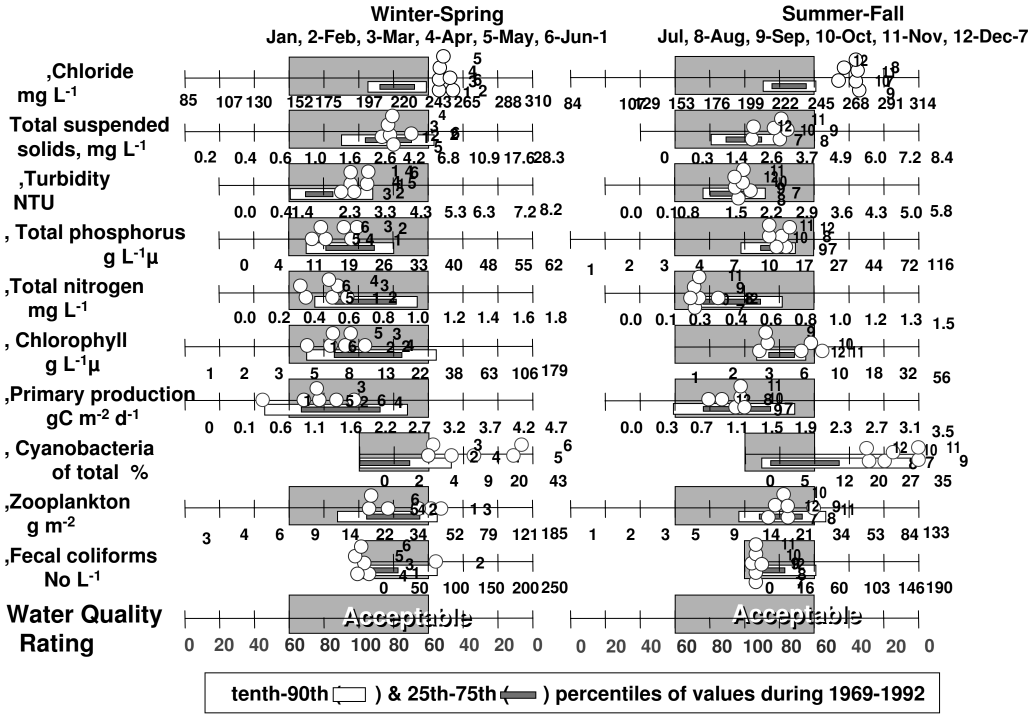

Figure 6. Monthly water quality index for Lake Kinneret in 2000. (After Hambright *et al*. 2000). Each monthly average is marked by its number on different scale for each parameter. The grey rectangles represent acceptable values for each parameter, the white rectangles represent 10^{th} to 90^{th} percentiles and the dark rectangles represent 25^{th} to 75^{th} percentiles. (Data collected by Alon Laboratory of the National Oceanographic and Limnologic Organization, KLL).

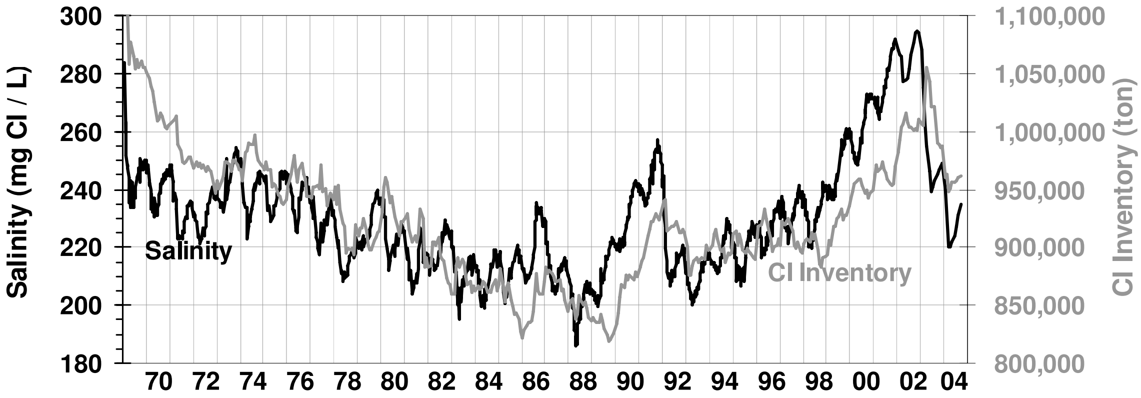

Figure 7. Salinity (in mg Cl L^{-1}) and Cl inventory (in tons) of Lake Kinneret 1969 - 2004. (Data collected by KLL, Hydrological Service).

Salinity of Lake Kinneret water is a major concern. The water from the lake is transported to the centre and south of Israel, and much of it is used for irrigation. The salts are deposited in the ground, reduce the productivity of soils and raise the salinity of the native groundwater in the aquifers. It is therefore imperative to keep the salinity of the lake as low as possible. It shown in Figure 7 that in the salinity of the lake decreased from a range of 380 mg Cl L^{-1} in the early 1960's to a minimum of 180 mg Cl L^{-1} in 1988, then increased to almost 300 mg Cl L^{-1} in 2002 and decreased again to 230 mg Cl L^{-1} in 2004. This relatively high Cl^- concentration reflects mixing of low salinity (15-30 mg l^{-1}) water from the Jordan River and other streams with highly saline (1000-18,000 mg l^{-1}) littoral springs (Kolodny *et al*. 1999). The Salinity Diversion Channel (SDC) along the west shore of the lake was constructed in 1967 to divert saline water from springs and wells located in the northwest and west side of the lake (Nishri *et al*. 1999).

There have been many studies of the mechanism of salinisation of the lake, and still there are open questions on this matter. The most plausible mechanism is entry of saline waters from below, driven by hydraulic pressure of recharge in the uplands on saline waterbodies in the layers below the lake (Goldshmidt *et al*. 1967; Gvirtzman *et al*. 1997; Rimmer *et al*. 1999; Abu *et al*. 2003). Monitoring the salinisation process in Lake Kinneret is carried out by calculation of a salt mass balance. The contribution of the unmonitored saline springs is an unknown component in this mass balance, hence it is calculated by closing the balance equation of the other measured components (Assouline 1993). A major advance in the methodology is simultaneous solution of the water volume, heat content, and salt mass equations in the lake (Assouline 1993). Another problematic component in the salt mass balance is the salt content in the lake. Calculation of this component requires mapping of the spatial distribution of salinity throughout the lake, which is one the tasks of the monitoring system. In Figure 7 the calculated Cl inventory of the lake is shown. It is indicated that the Cl inventory reduced from about 1,100,000 tons before to a minimum of 820,000 tons in 1989, then increased to 1,050,000 tons in 2002 and slightly reduced through 2004.

5. MODELING AND DATABASES

Many models have been developed and used over the years, to aid in understanding the processes in the lake and its watershed, to guide the monitoring system design and operation, and to form the basis for water management decision-making. The models range from simple statistical analysis of individual water-quality parameters, through correlations in time and space among different parameters, to compartment and numerical models of processes in the lake. The interested reader is referred to the database http://wri.technion.ac.il/cgi-bin/abstract.html.

A major modelling effort for the lake has been under way in recent years to produce a scientifically based, operational decision-support system for management of Lake Kinneret. This project is financed by the Water Commission and is carrying out by a collaboration between the Alon

Laboratory of the IOLR (KLL) and the Centre for Water Research at the University of Western Australia (CWR). The system is based on a combination of long-term (years) and short-term (days) hydrodynamic simulation models, DYRESM (one-dimensional) and ELCOM (three-dimensional). An ecological model, CAEDYM, will be used to simulate the biogeochemical processes in the lake. This project is expected to simulate the entire physical-ecological structure of the lake and to provide a basis for evaluation of changing conditions and proposed decisions. The main scenarios to be examined are lowering the water level below –214 m, diverting Jordan River water north of the lake directly to the National Water Carrier (thus bypassing the lake), introducing large amounts of Yarmouk River water to the lake and changes in nutrients load from the watershed. The model project is expected to help in improving the monitoring system, determining which are the parameters that need to be monitored, where and how frequently, as well as to focus further research on the physical, chemical, and biological processes in the watershed and the lake. The first phase of the project was completed successfully in summer 2000, when calibration runs passed the acceptance tests (http://www.cwr.uwa.edu.au/~contract/Current_projects/kinneret.html,). The second phase involves further development of the models and their application to address a set of event analysis and management scenarios as mentioned above. The second phase as well as the whole project should be submitted to the Water Commission in mid 2005.

A new database (Orakel 2000) is being planned, which will incorporate the data from all sources and different bodies. This data base will be connected to a GIS system (ArcGIS 8) and be available to everyone who has a need for the information and a legitimate role to play in analyzing and managing the lake or the watershed. A spatial data base of the PS and NPS pollution in Lake Kinneret Watershed was built on ARGUS ONE software since 1998 (DHV MED 2000). The total pollution emission was defined by several characteristics of the pollution contributors such as the concentration at the source, load per unit area and the source area. Quantifying the concentration at the source and the load per area of the various pollution sources was based on a literature survey and information collected from the field by the authorities. These coefficients were integrated into the system to provide the pollution contributions based on the relations between attributes of the pollution zones such as their topologies (shape, area, length) and their use (agriculture, urban, grazing). This spatial data base allowed us to estimate the emission coefficients for the relative pollutants (mainly phosphorus, nitrogen, sediment, pesticides and herbicides) as shown in Fig. 2 for phosphorus from grazing areas.

A comprehensive, GIS-based modelling approach that was developed to enable accurate prediction of nutrient loads in watersheds (AVGWLF, Evans *et al.*, 2002) will be used for Lake Kinneret watershed in the near future. The model will rely on the GIS data base for deriving reasonably good estimates for various critical parameters. The transportation model will be calibrated against the monitoring data of the downstream stations. This will enable to evaluate the retention capacity coefficients for the different basins in the watershed, hence to evaluate the pollution load in different management scenarios (Novotny and Olem, 1994; Novotny, 2003).

6 INTEGRATED LAKE-WATERSHED MANAGEMENT

The management functions of Lake Kinneret are mainly subjected to 3 different issues:

1. Manipulating the water level of the lake as a function of pumping amount in result to different climate events. As shown in Figure 2 the lake level may be changed in a limited range between upper and lower operational levels (red lines). In a very severe drought years it is up to the water commissioner to decide which water resource to exploit more, hence whether to let the Lake Kinneret water level to drop below the "red line" or one of the aquifers.
2. Fishery management that may help conserving the ecosystem of the lake. Although very this subject is controversy even between researchers, it is still considered as a management tool for Lake Kinneret. Since the 1990's about 6 million of young *Telapia galilaea* fish were introduced to the lake annually. This endemic Kinneret fish (also known as St. Peter's fish) is suppose to be nourished from algae rather than zooplankton (Serruya, 1978). Therefore adding *Telapia galilaea* to the lake should help in reducing biomass of algae. However, the small fish *Mirorex terraesanctae* known also as Sardin tabarya is excluded from the lake. Since this fish is nourished mainly from zooplankton it is assumed that its population in the lake should be limited. Therefore, about 800 tons of Sardin are excluded from the lake annually, out of which 500 is commercial fishery and the rest is subsidized by the Water Commission.

3. Preventing the leaking of PS (point source) and NPS (non point source) pollution from the watershed to the lake. A serious of management steps were taken regarding this issue since 1970. Most of the sewage is treated in waste water plants, collect in reservoirs and is used for irrigation during the dry summer. Most of the dairy farms in the watershed were removed or rebuilt with septic systems to prevent downstream leakage. Some of the fish ponds in watershed were removed and some are forced to circulate their utilization water. The main pollution that was not treated so far is the diffuse or non point pollution. (Markel 2003) The diffuse pollution is mainly sourced in agricultural fields, pasture areas and surface runoff. A new decision support tool, called PRedICT (Pollution Reduction Impact Comparison Tool, Evance *et al*. unpubl.) will also be used to evaluate the implementation of both agricultural and non-agricultural pollution reduction strategies. Various "scenarios" of management practices (like fertilizing and pest control practices, buffer strips and constructed wetlands) will be exanimate for pollutant loads (both PS and NPS). These scenarios will help to develop best management practices (BMP) for minimizing diffuse pollution load on Lake Kinneret.

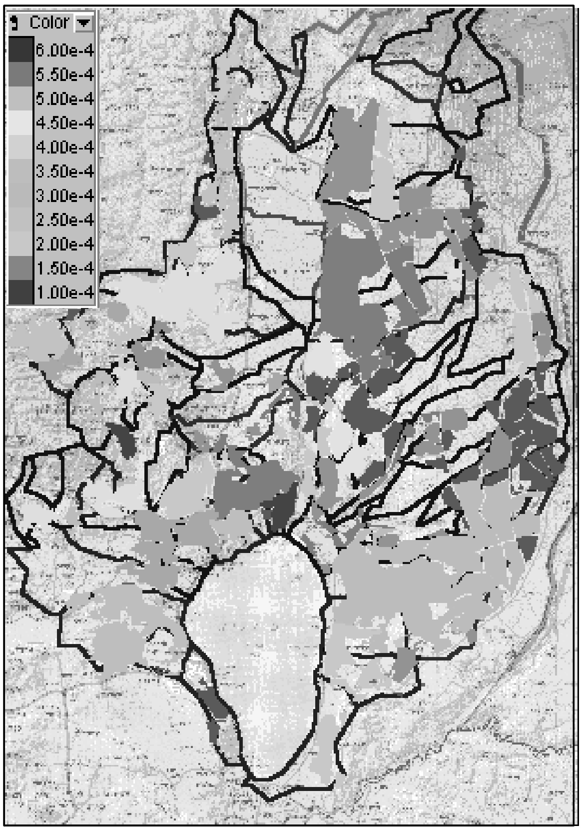

Figure 8: evaluating the phosphorus emission (in kg m^{-2}) from grazing areas in Lake Kinneret watershed, as produced by the ARGUS ONE software that was developed by DHV MED (DHV MED 2000)

7. CONCLUSIONS

The monitoring system in Lake Kinneret and its watershed has evolved over several decades. Since 1998, a new organizational structure is in place, to direct and coordinate the work of the several entities that collect and analyze flow and water-quality data.. This structure has resulted in improved effectiveness and efficiency of the monitoring and analysis system, developing models of processes in the lake and its watershed and hence improved the ability of decision-making regarding the management of Lake Kinneret and its watershed.

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