Chapter 1
General Background

Tom Berman, Tamar Zohary, Ami Nishri and Assaf Sukenik

Abstract The introduction presents a short historical background of the region, including an account of research on Lake Kinneret. An account of recent anthropomorphic changes that have impacted the lake ecosystem and data on morphometric, bathymetric, and other basic limnological characteristics of the lake are given. The main features of the annual cycle of key limnological parameters (temperature, stratification, chlorophyll, pH, dissolved oxygen, nutrients, sulfate, and sulfide) are presented.

Keywords Sea of Galilee · Lake Hula · Kinneret Limnological Laboratory (KLL) · Israel Oceanographic and Limnological Research (IOLR) · Mekorot · National Water Carrier (NWC)

1.1 Historical Background

Human settlement around the shores of Lake Kinneret reaches far back into antiquity and, in fact, predates the modern lake, which has existed in its present form for only some 18,000 years. At Ubadiya, about 2 km southwest of the lake, lies a habitation site which is one of the earliest prehistoric sites yet discovered and which may have been a way station on the migration route of early mankind out of Africa. Surrounded by exotic tropical flora, communities of *Homo erectus* flourished here 1.4 million years ago, as attested by the discovery of fossilized fragments of skull bones and teeth in addition to collections of animal bones and stone artifacts. Subsequent geological upheavals buried these sites and altered the form of the lake. Evidence for later, but still prehistoric settlement, was found in the karst caves of Wadi Amud northwest of the lake where the remains of "Galilee Man," an

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T. Zohary (✉) · T. Berman · A. Nishri · A. Sukenik
The Yigal Allon Kinneret Limnological Laboratory, Israel Oceanographic
& Limnological Research, P.O. Box 447, 14950 Migdal, Israel
e-mail: tamarz@ocean.org.il

A. Nishri
e-mail: nishri@ocean.org.il

A. Sukenik
e-mail: assaf@ocean.org.il

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early human who lived there 100,000–150,000 years ago, were discovered together with artifacts from the Middle and Upper Paleolithic periods (40,000–100,000 and 20,000–40,000 years ago).

In 1989, during a period of minimum lake level, an Upper Paleolithic "village" of fishermen-hunters was discovered at Ohalo on the southwestern shore (Fig. 1.1). The remains of six charcoal rings where brushwood dwellings had been erected, a grave, and an area that was probably used as a refuse dump were uncovered. This site was probably occupied for only a few generations, but nevertheless its discovery has greatly expanded knowledge of prehistoric hunting and gathering practices.

At Tel Bet Yerach, near Ohalo (Fig. 1.1), 16 identifiable strata of civilization have been revealed, beginning with the Chalcolithic and ending with the Arab. The site was inhabited from the Early Bronze Age (3300–2300 BCE). The Hellenes knew this place as Philoteria, so named after the sister of Ptolemy Philadelphus, the Hellenic king of Egypt; the Romans, in their day, called the town Ariah. After them came the Byzantines and then the Arabs, who named the place Kerak. Close by, in 1909, came a group of seven Jewish settlers to till the lands at Umm Juni and to establish the first kibbutz, Degania. Here, as at many historical sites around the lake, can be found stone testaments to former glories: a second-century synagogue, a fourth-century Roman bathhouse, and a sixth-century Byzantine church.

In ancient times, the natural hot and salty springs around the lakeshores were famous for their healing properties. An Arab folk tale attributes the heat of these springs to a pack of demons assigned to this task by King Solomon. Although this is deemed unlikely by today's hydrologists, the exact sources of the warm, saline waters and the mechanisms responsible for their upwelling within and around the lake have been subject to considerable scientific debate (Chap. 7).

In Greek, Roman, and Byzantine times, a large population, perhaps as many as 50,000–100,000, lived around the lake. The most widely renowned are places mentioned in the New Testament, but these represent only a small portion of the many settlements and towns which flourished in the region. The lake, also known in English as the Sea of Galilee or Lake Tiberias, figures prominently in the life of Jesus and his ministry. Several of his prominent disciples were local fishermen, and many of his activities and miracles took place in the area. During Vespasian's suppression of the Jewish Great Rebellion against the Romans (67–70 CE) in Galilee, the regions around the lake witnessed many bloody events, including a horrendous siege at Gamla and a lake battle off the coast of Migdal (Fig. 1.1).

After the relatively prosperous times of Roman and Byzantine rule came a period of decline, with first Arab, then the Crusader, and again Arab conquests. At the Horns of Hittim, a prominent place about 8 km to the west of Tiberias, a decisive battle was fought on a blazing hot Fourth of July in 1187 between a Saracen army commanded by Saladin and the Crusader knights under King Guy. The defeat of the Crusaders marked the end of the First Kingdom of Jerusalem and destroyed aspirations for Christian sovereignty over the Holy Land.

In the mid-sixteenth century, Tiberias (Fig. 1.1) enjoyed a brief revival when the Ottoman sultan Suleiman the Magnificent granted Doña Gracia and her nephew Joseph Nasi a permit to establish an autonomous Jewish region there. However, by

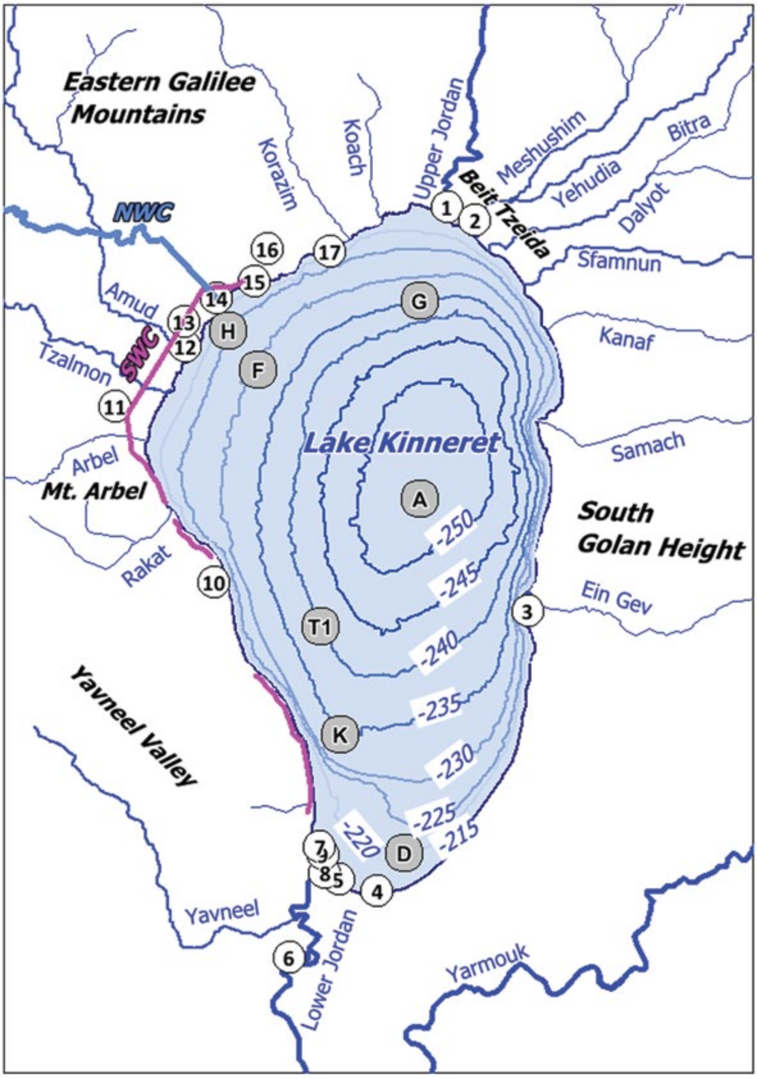

Figure 1.1 Map of Lake Kinneret and its surroundings, showing locations of in-lake sampling stations (*gray circles*) and major archeological and historical sites (numbered *white circles*). Lake bathymetry is shown at 5-m intervals, with absolute altitude (m, amsl) indicated. Sites around the lake (alphabetic order): Bet Yerach—7, Capernaum—17, Degania Dam—9, En Gev—3, Jordan River inflow—1, Jordan River outflow—5, Kinneret Limnological Laboratory and the National Water Carrier pumping station of Mekorot Water Company at Sapir Site—14, Meshushim inflow—2, Migdal—11, Mount of Beatitudes—16, Ohalo—8, salt diversion canal—13, Tabgha—15, Tiberias—10, Ubadiya—6, Wadi Amud—12, Yarmouk diversion inflow—4. *NWC*—National Water Carrier. *SWC*—saltwater diversion canal. (Original, by Alon Rimmer)

1596, Tiberias had declined to a total recorded population of 50 Muslim families and four bachelors. During the eighteenth and the nineteenth centuries, the town and region suffered mixed but mostly ill fortunes, including sieges, sacking and pillage, and a devastating earthquake in 1837.

Throughout the centuries, the Sea of Galilee has attracted visitors, both pious and profane, whose journals chronicle the vagaries of the region's history. These had reached a nadir by the mid-nineteenth century under the Ottoman neglect and misrule. Some modernization came in 1889 with a group of German Catholics who built a hospice and had a relatively large farm at Tabgha, the present-day site of Israel's National Water Carrier (NWC) pumping station and the Kinneret Limnological Laboratory (KLL; Fig. 1.1). Nearby areas surrounding Capernaum and the Mount of Beatitudes were bought by the Franciscans in 1891 and Italian Catholics at the beginning of the twentieth century, respectively. The first clinic in the whole area was opened in Tiberias in 1894 by a Scottish doctor, David Torrance. Even as recently as 100 years ago, the region was without paved roads or telegraph, and rampant with malaria and bandits. An air photograph from ~1912 (Fig. 1.2) provides evidence that not a single tree existed around the southern shores of the lake at that time, with most of the useable timber in the region having gone into the building of the Hejaz railway and fueling its locomotives.

The influx of Jewish settlement around the lake and throughout the Kinneret watershed, beginning with the establishment in 1910 of Degania, the first kibbutz, brought development, increased prosperity (Fig. 1.2), and, subsequently, led to the growing threats of pollution and environmental degradation.

1.2 Research on Lake Kinneret

Scientific curiosity about the Sea of Galilee has been considerable over many centuries. Physical limnology was touched upon, albeit somewhat inaccurately, by Josephus Flavius (37–100 CE), who asserted that the waters of the River Jordan flowed directly along the lake bottom from the inflow in the north to the outflow in the south. He also summarized lake chemistry by simply stating, "Its waters are pure." A limnograph appears on the sixth-century mosaic floor in the Byzantine church at Tabgha, the reputed site of the New Testament miracle of the loaves and the fishes. Among the early travelers to this region were scientists such as Haselquist, a student of Linnaeus, from Sweden, and excellent naturalists like MacGregor (1870) from Scotland, who recorded lively descriptions of the lake and its flora and fauna. For example, we learn from Burckhardt (1822), the Swiss discoverer of Petra, that in the early 1800s the most common fish were the Binnit (*Barbus longiceps*) and St. Peter's fish (*Sarotherodon galilaeus*), species which are still found today. Naturalists such as Tristram (1884), Barrois (1894), and Annandale (1912, 1915) examined and tabulated the flora and the fauna of the lake in the 1860s and in the early years of the twentieth century, respectively. Annandale (1915) also made remarkably detailed and accurate measurements of water temperatures and chemical composition. Somewhat later, from 1914 to 1918, Fr. Schmitz, a German naturalist, ornithologist,

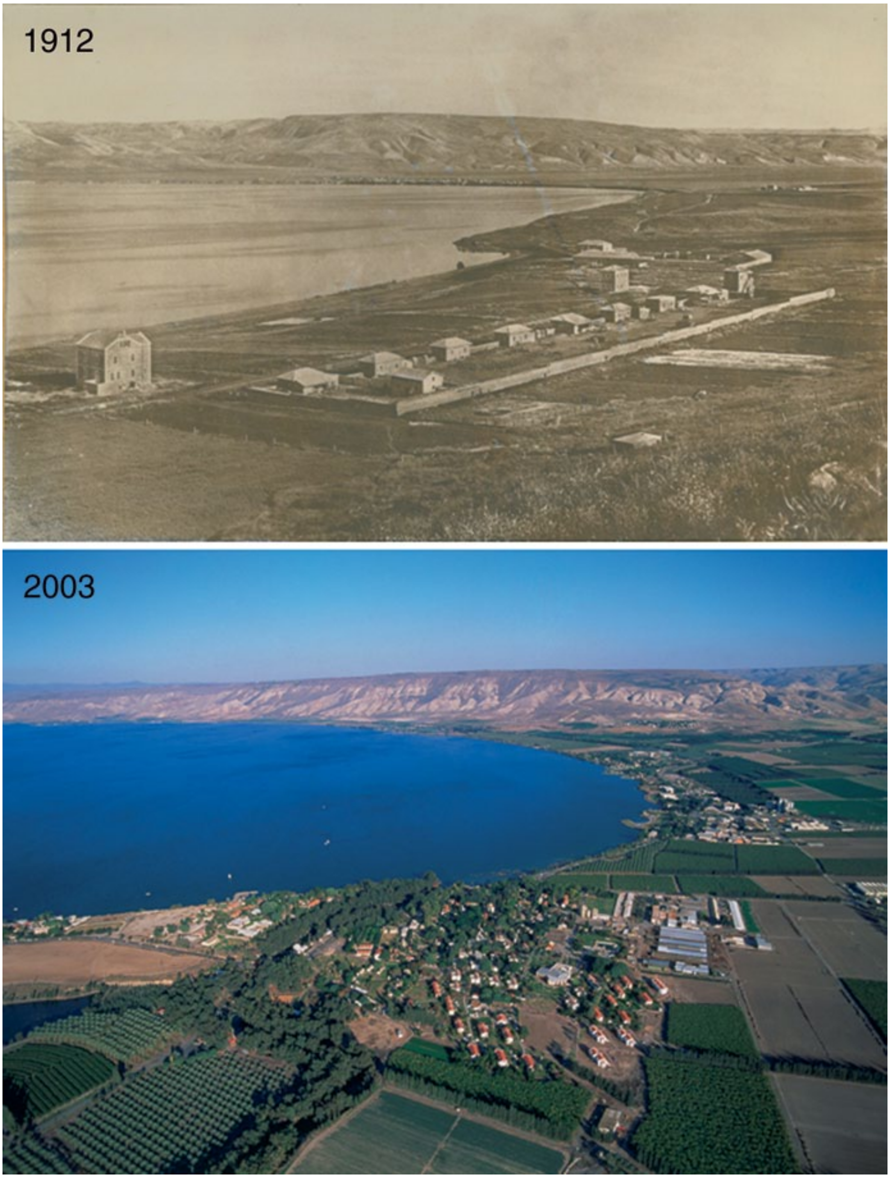

Figure 1.2 Air photos of the southern part of Lake Kinneret and Golan Height: past and present. *Upper* photo taken by the Turkish Air Force circa 1912; note the bare land and lack of trees. (*Lower* photo taken by Albatross Aerial Photography Ltd., in 2001, reproduced with permission)

entomologist, and Roman Catholic priest carried out extensive natural history studies in Palestine, including the shores and waters of Lake Kinneret.

From 1920 to 1950, scientific studies remained mainly of a descriptive nature and were directed principally toward improving the catch of the commercial fishery. In the late 1950s, some careful but limited investigations on the physical and chemical characteristics of the water (Oren 1957) and the photosynthetic activity of the algae were carried out by Yashouv and Alhounis (1961). Only after 1960, with the decision to use Lake Kinneret as the principal reservoir of the NWC system, was an effort made to encourage more systematic studies of the lake. Mekorot Water Company, which is responsible for most of the water supply in Israel, began to monitor water samples from the lake and catchment area. Scientists from various institutions were funded by Mekorot to carry out research projects, while Tahal (a semipublic company that was at that time responsible for the development of new water sources) undertook to study the hydrology of the saline inputs.

Although well intentioned, these first attempts at a comprehensive research program yielded only fragmented results. Partly, this was because most of the scientists involved spent little time at the lake and thus their work lacked continuity. More important factors were the lack of coordination and understanding of ecological priorities, which caused many independent projects, some of marginal importance, to be funded.

In 1965, Mekorot invited an eminent Swedish limnologist, Wilhelm Rodhe, to appraise the state of the water quality. Somewhat alarmed at seeing a dense bloom of *Peridinium,* Rodhe predicted that a further deterioration of water quality might be expected, and recommended the establishment of a lakeside laboratory for scientific study of the lake. At approximately the same time, the Israeli government set up an organization that became Israel Oceanographic and Limnological Research (IOLR). In turn, this led to the establishment of the KLL in 1968.

With the inception of the KLL, the modern era of closely integrated monitoring and research began. Starting in October 1969, five main sampling stations (Fig. 1.1) were visited weekly or fortnightly to collect water samples for chemical and biological determinations, generating data that today constitute the Lake Kinneret Database. A first monograph entitled "Lake Kinneret," edited by Colette Serruya, was published (Serruya 1978), putting a solid basis to the understanding of the structure and functioning of this warm, monomictic freshwater lake. Since then, more than 1,000 additional scientific papers addressing Lake Kinneret have been published in the peer-reviewed literature. A comprehensive list of research literature up to 1999 was compiled by Hambright. Our objective in the present monograph is to summarize current knowledge on the Kinneret ecosystem, accumulated over four decades of intensive research and monitoring, in a single volume accessible to the professional community.

1.3 Morphometric and Limnological Features of Lake Kinneret

Lake Kinneret is located in the northern Syrian–African Rift Valley, at 32°50′N, 35°35′E. Some main morphometric and limnological features are summarized in Table 1.1. The lake is subject to a Mediterranean climate, with hot, dry summers and cool, wet winters, with rainfall and nutrient inflows limited to 4–6 months of the year (usually from October–November to February–March). Lake bathymetry and also the main sampling stations for the monitoring program are shown in Fig. 1.1. Detailed bathymetric and morphometric data can be found in Chap. 4.

Table 1.1 Morphometric and other characteristics of Lake Kinneret. Morphometric features are measured at a baseline water level of −209 m[a]

Age (modern freshwater lake), years	~20,000
Surface area, km^2	168.7
Mean depth, m	25.6
Maximum depth, m	41.7
Volume, 10^6 m^3	4,325
Maximum length (North–South), km	21
Maximum width (East–West), km	12
Perimeter, km	56
Shoreline development index	1.16
Latitude, °N	32°50′
Longitude, °E	35°35′
Altitude, m a.m.s.l.	−209
Annual Jordan River inflow volume (mean 1971–2010), 10^6 m^3	450
Water residence time, years	7–11
Watershed area, km^2	2,730
Typical thermocline depth in June, m	15
Lower water mass volume, 10^6 m^3	1,600
Epilimnion volume, 10^6 m^3	2,700
Lake floor area covered by hypolimnion, km^2	135

[a] Altitude measurements are given relative to above mean sea level (amsl)

1.4 Seasonal Patterns of some Limnological Parameters

Lake Kinneret is a warm, monomictic meso-eutrophic subtropical lake that is stratified annually from March–April to December–January. During stratification, an aerobic warm (24–30 °C) epilimnion and an anoxic relatively cold (14–16 °C) hypolimnion are formed. Seasonal variations in some characteristic parameters are shown in Fig. 1.3. Multi-annual averages (based on data from 2000 to 2011) for these parameters indicate major differences between epilimnion and hypolimnion with a typical seasonal pattern. The following section gives a brief description of these parameters. Further details on seasonal dynamics and multi-annual variations in physical and chemical driving forces (water flow, nutrient loads, and meteorological parameters) as well as on various biological parameters in Lake Kinneret are presented in the relevant chapters of this book.

Water and air temperatures (Fig. 1.3A). Epilimnetic water temperature shows a gradual rise in accordance with air temperature (*solid line* in Fig. 1.3a) until mid-summer. Subsequently, air temperature drops below epilimnetic temperature inducing the gradual cooling of the upper water column. About a month after the onset of seasonal stratification, the mid-thermocline depth (Fig. 1.3b) begins at 14 m and gradually deepens, typically at 1 ± 0.4 m per month, until October, after which this rate increases. Hypolimnetic temperature (Fig. 1.3a) increases very slowly, only by ~ 1°C throughout the stratified period.

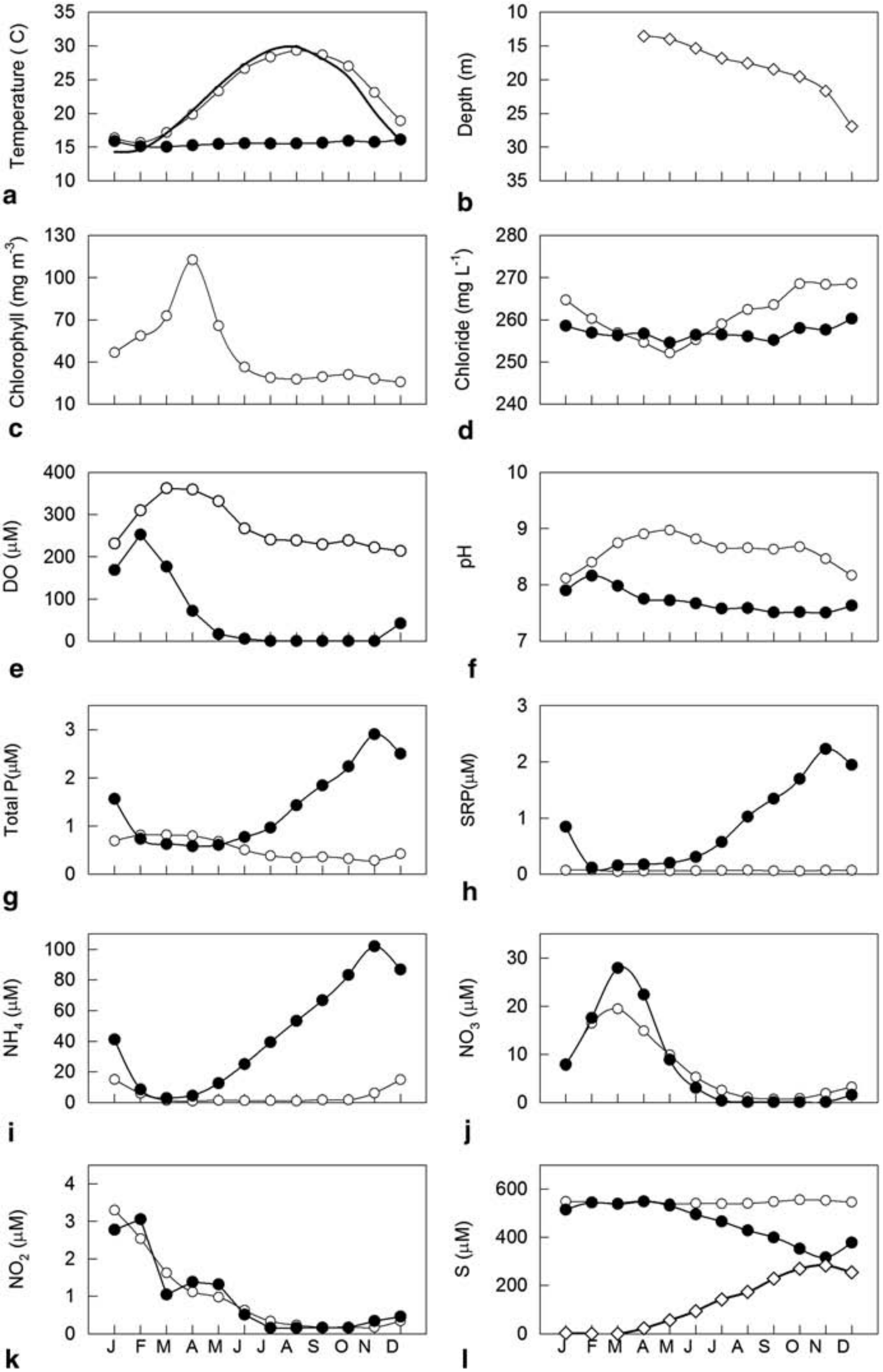

Figure 1.3 Monthly averages of limnological parameters in Lake Kinneret for the decade 2001–2011 in the upper 0–5 m (*empty circles*) and lower >30 m (*solid circles*) water layers at station A. **a** *Solid line* shows air temperature. **b** *Diamonds* represent the depth of the mid-thermocline. **l** *Diamonds* represent the hypolimnetic sulfide concentrations, *empty circles* and *filled circles* refer to sulfate concentrations

Chlorophyll (Fig. 1.3c). Winter–early spring is characterized by a steep rise in chlorophyll (Chl) concentrations to a maximum in April. The crash of the spring bloom in late spring or early summer is indicated by a decline to significantly lower levels of ~ 120 ± 30 mg Chl m^{-2} that prevail throughout the rest of the year.

Chloride (Fig. 1.3d). Epilimnetic chloride concentration (*empty circles*) decreases during the winter–spring due to freshwater inflows. Starting in May, reduced freshwater inflows combined with the continuous inflows of saline springs and evaporation lead to a rise in epilimnetic Cl^-. Hypolimnetic Cl^- (*filled circles*) remains practically unchanged with a hardly detectable Cl^- raise in October–November, equivalent to ca. 1,000 t. This Cl^- originates from molecular diffusion of pore-water brine underlying the lake pelagic floor.

Oxygen (Fig. 1.3e). The lake surface-water layer is supersaturated with respect to oxygen in spring due to enhanced primary production and weak winds that reduce gas exchange fluxes. Subsequently, the crash of the spring bloom, solar warming of the surface layer, and the incidence of strong westerly winds cause the dissolved oxygen (DO) levels in the near-surface-water layer to be more or less at saturation. In the hypolimnion, DO declines when the lake stratifies and by June, this layer becomes fully anoxic. Anoxia is maintained until turnover in December or January.

pH. In winter–early spring (April), epilimnetic pH (Fig. 1.3f) rises well above 9.0 reflecting high photosynthetic activity and low wind stress that limit CO_2 replenishment from air. In the hypolimnion, pH drops during the stratified period due to CO_2 and H^+ accumulation caused by biodegradation of organic matter.

Particulate phosphorus (Fig. 1.3g). In the epilimnion, particulate phosphorus (PP = total P minus total dissolved P) slowly accumulates in winter–spring. When the spring bloom crashes, PP declines to levels of about one-third of peak spring levels mainly through sedimentation. Hypolimnetic PP begins to decline in late winter–spring probably due to the sedimentation of allochthonous and possibly also due to some autochthonous PP formed during the mixing period.

Soluble reactive phosphorus (SRP) (Fig. 1.4h). Epilimnetic SRP concentrations are mostly at or below the detection limit (~0.2 μM) at all times of the year. Hypolimnetic SRP accumulates gradually, reaching concentrations of ~2.5 μM by the end of the stratification, then gets diluted by mixing with epilimnetic water at turnover.

Ammonium (Fig. 1.3I). Ammonium (NH_4) accumulates in the hypolimnion during the stratified period in summer–fall reaching concentrations of ~110 μM. In the epilimnion, NH_4 concentrations are at or below detection limits. A small peak of NH_4 occurs in winter during the mixed period in both epilimnion and hypolimnion.

Nitrate (Fig. 1.3j). Nitrate (NO_3) accumulates in winter due to riverine inflows and nitrification of NH_4 previously accumulated in the hypolimnion. In March, when stratification usually begins, the NO_3 concentrations in the epilimnion are lower than in the hypolimnion, due to active uptake by phytoplankton. Thereafter, NO_3

concentrations continue to drop in both the epilimnion and hypolimnion due to biological uptake and denitrification, respectively.

Nitrite (Fig. 1.3k). Nitrification–denitrification processes are evident from nitrite (NO_2) peaks in winter in both layers and in spring in the hypolimnion. Nitrite concentrations resulting from nitrification and denitrification processes are highest during the mixed period and close to detection limits for the remainder of the year.

Sulfate and sulfide (Fig. 1.3l). Sulfate (SO_4) in the oxic epilimnion is a conservative ion affected mainly by water evaporation. However, microbial SO_4 reduction in the anoxic hypolimnion, beginning in June, leads to a drop in SO_4 and an accumulation of hydrogen sulfide (HS^-, *empty diamonds*) reaching 0.27 mM in November.

1.5 Man-Induced Changes that Impacted the Lake Kinneret Ecosystem

Until construction of the Degania Dam in 1932, Lake Kinneret could be considered as a natural habitat with only minor influence of human activity. Since then, Lake Kinneret has been subjected to a series of anthropogenic changes that have substantially impacted the lake ecosystem. Today, the lake essentially functions as a regulated large water reservoir, with consideration given to its three main uses: water supply, recreation, and fisheries.

Here, we briefly review the major anthropogenic changes, which have occurred over the past 80 years within the Kinneret watershed, in and around the lake. A chronological listing of these changes is given in Table 1.2. Current demographic and socioeconomic data pertaining to the Kinneret Basin are given in Chap. 30.

Degania Dam: Prior to 1932, there were no major anthropogenic hydrological alterations to Lake Kinneret. Archeological evidence from Biblical-era shore structures as well as modern records from 1926 to 1932 of lake water level indicate that under natural conditions, lake water levels fluctuated annually by ~1.5 m, between a minimum of ~−210.5 m a.m.s.l. in fall and a spring maximum of ~−209.0 m. In 1932, the natural outflow at Bet Yerach was blocked. The new outflow to the southern Jordan River was controlled by a dam that regulated water flow to the Rutenberg Hydroelectric Plant at Naharayim, which operated from 1930 to 1948. The Degania Dam increased the annual fluctuation of water level to 2–3 m. The British Mandatory Authority established permissible limits to these fluctuations with −209 and −212 m as upper and lower levels, respectively. Over the past 44 years, the Degania Dam was opened to release water downstream only on relatively few wet winters (Chap. 7).

Draining of Lake Hula and adjacent wetlands: A drastic change to the Kinneret catchment basin and its hydrology occurred in the 1950s with the draining of Lake Hula and its adjacent wetlands. This major engineering project was undertaken in

Table 1.2 Major anthropogenic changes in Lake Kinneret and its catchment since 1927

Year	Event
1927–1932	The Degania Dam was built on the Jordan River outflow, impounding the lake; outflow deepened to −214 m. Legal maximum and minimum water levels ("*red lines*") were set at −209 and −212 m (based on current altitude measurements)
1932–1948	Hydroelectric production at Naharayim, lake levels were manipulated at larger amplitudes than natural but within −209 and −212 m
1951–1958	Drainage of Lake Hula and surrounding swamps in northern catchment
1952–present	Stocking fingerlings of fish of commercial value, which also contribute to improving water quality (St. Peter's fish, grey mullets, silver carp)
1956–1964	Construction of the National Water Carrier (NWC)
1964–present	Lake Kinneret water is pumped into the NWC from Sapir Site. Since 1973 the NWC operated at full capacity ($300–400 \times 10^6$ m^3 pumped annually, reduced to $\sim 200 \times 10^6$ m^3 with increasing water from desalination since 2012
1967–present	Diversion of offshore saline springs via a salt-water diversion canal to the southern Jordan River
1978–present	Actions to reduce effluents of domestic and agricultural origin, including sewage treatment plants, reduction of fishpond area and recycling of their effluents, and treatment of cowshed effluents. In 1984, the Einan Reservoir was constructed to contain and treat effluents from Kiryat Shmoneh and western Hula basin and recycle them for local agriculture
1981	Legal minimum water level lowered to −213 m
1980s–2000s	Construction of water storage reservoirs in the Golan Heights, storing $\sim 40 \times 10^6$ m^3 of water, for agricultural and domestic use
Early 1990s	Construction of "spurs" at various swimming beaches around the lake, later found to disrupt the natural near-shore flow of water and particles
1994–1999	Hula restoration. Raising the groundwater table; creation of Agmon Wetland, improved drainage and recycling of western Hula Valley water for local use aimed at controlling the flow of water from the Hula Valley to Lake Kinneret
1998–2000	Deepening the Jordan River between Pkak Bridge and Benot Yaacov Bridge for improved drainage control
1995–2006	Subsidized harvest of bleak (Kinneret sardine) to reduce predation on zooplankton and improve water quality
1999–2008	Due to shortage of freshwater, legal minimum water level progressively lowered below −213 m (lower red line). In 2008, the lowest legally permissible water level was declared as −214.87 m. (*Lowest recorded water level, Dec. 2001*)
2012	Local actions to remove shoreline/inundated vegetation and treat mosquito larvae resulting from the 2011/2012 increase in water levels that followed a series of drought years

order to provide arable land for the many settlements that were established in the area and to control the blight of mosquito-borne malaria, which was rampant in those years. Lake Hula was a natural shallow lake, about 25 km upstream of Lake Kinneret, that contained dense macrophyte stands and functioned as a natural pre-impoundment, filtering the inflowing Jordan River water (Dimentman et al. 1992; Hambright and Zohary 1998). The peat-like soils of the drained Hula Valley became a major source of nitrates and sulfates to Lake Kinneret through aerobic decomposition of their organic matter, followed by nitrification (Nishri 2011).

The NWC: Israel's NWC system began operation in May 1964. Subsequently, most of the outflow from Lake Kinneret was pumped into this water delivery system; from the 1970s until the mid-2000s, amounts ranging from 300 to $>400\times10^6$ m^3 were pumped annually from the lake. By contrast, annual outflow via the southern Jordan was limited to 18–20×10^6 m^3. Greater discharge through the Degania Dam only occurred in two winters of high water levels with exceptional precipitation (1968/1969, 1991/1992). The altered pattern of water removal since 1964 resulted in a major change in the timing of maximum water and nutrient removal from the lake (Hambright et al. 2004). Prior to 1964, the discharge volume was greatest during the winter holomixis, when outflowing waters are nutrient rich. Since then, maximum outflows have occurred in summer and fall because of increased pumping needed for agricultural irrigation and domestic supply. In this season, the lake is stratified and surface waters are nutrient depleted. In the long run, the change in outflow regime since 1964 reduced the export of nutrients from the lake.

Local water supplies: In addition to the water pumped from the lake into the NWC, over the past 50 years, numerous small pumping stations were constructed around the shores for local agricultural and domestic needs. The municipal water supply for the town of Tiberias (population ~40,000) is taken directly from the lake. Another large pumping station, situated on the southeastern shore, supplies water to a large rural area south of the lake. In all, these pumping stations supply about 40×10^6 m^3 annually. Since the peace agreement with the Kingdom of Jordan in 1995, an additional 50×10^6 m^3 are pumped annually and transferred to Jordan.

Diversion of saline springs: Concurrently with the construction of the NWC during the 1960s, actions were taken to reduce the salinity of Lake Kinneret so that water provided via the NWC was more suitable for irrigation. A salt water carrier was constructed as a bypass, which channelled $\sim20\times10^6$ m^3 annually from saline springs along the northwestern coast into the southern Jordan River. Later, treated sewage from settlements and Tiberias was diverted into this bypass to prevent it from reaching the lake. Operation of the salt water carrier caused a continuous decline in the salinity of Lake Kinneret during the 1970s and 1980s (Nishri et al. 1999). Since the late 1980s, however, salinity levels have gradually increased (for details, see Chap. 8).

Upstream water consumption: After 1967, intensive agriculture was introduced in the Golan Heights and the need for water led to the construction of several reservoirs to retain floodwater. These reservoirs, located within the Kinneret catchment, have a total storage capacity of 40×10^6 m^3 and hold water that would otherwise reach Lake Kinneret. Expansion of agricultural and municipal and domestic use, including groundwater withdrawal throughout the catchment area, has further contributed significantly to the reduced annual inflow volume when compared with the volume three to four decades ago (more details in Chap. 7).

Einan reservoir: This 5.6×10^6 m^3 operational reservoir was constructed in 1983 to contain and treat high-nutrient and bacteria-containing secondary-treated effluents from Kiryat Shmoneh and the fishponds and cultivated fields of the southwestern Hula Valley, and thus prevent them from flowing into Lake Kinneret. The treated water is used for local agriculture.

Wetland restoration in the Hula Valley: For four decades, the Hula Valley was dry, with various ecological problems, such as aggravated soil erosion by high winds leading to dust storms, underground peat fires, soil subsidence, and loss of endemic species. Large areas of the acid peat soils proved problematic for intensive agriculture. In the early 1990s, a comprehensive plan was initiated to rehabilitate the southern Hula area. In order to raise the water table to prevent fires and soil erosion, a network of connecting canals was dug, and a small (1 km^2) shallow lake, Lake Agmon, was created in 1994. A barrier "curtain" of impervious plastic was placed across the southern end of the valley to prevent Hula groundwater from flowing into the Jordan River (Hambright and Zohary 1998). Lake Agmon and its surroundings have become a major way station for migrating birds (cranes, storks, pelicans, and many others), and ecotourism has supplemented agriculture as an income source. Since the completion of the Hula restoration project in 1998, most of the water draining the western side of the Hula Valley is recirculated locally for agricultural use and no longer reaches Lake Kinneret.

Fisheries management: Fisheries regulations for Lake Kinneret were originally set under the British mandate in the 1930s; most of these regulations are still valid. In order to increase the catch of commercial high value fish, a stocking program of both native and exotic species was initiated in 1952 and is still ongoing. The stocking could impact the balance between species competing for similar resources, and could cause decline in genetic variability of the stocked native species. Overfishing, especially during low-water-level years when the fish have less refuge, was associated with reduced body size of the commercial high value fish species, followed by a collapse of the commercial fishery in 2008. A controversial government-subsidized program that removed from the lake a total of 6,000 t of bleak (Kinneret sardine) over 11 years (1995–2006) was aimed at increasing zooplankton and improving lake water quality (see Chap. 36).

Shoreline development: In addition to being a major source of drinking water, Lake Kinneret is an important site for tourism and recreation which serve as a principal source of local income. This has led to continuous strong pressure for development of the lakeshores and shore properties for hotels, restaurants, and other tourist attractions. Development of swimming beaches and campsites has led to construction of access roads and parking lots, facilities for water sports, boat launching and mooring sites, etc.

In the early 1990s, several artificial embankments, up to 100 m in length and tens of meters wide were built perpendicular to the shoreline with the purpose of creating sites of quiet waters for swimmers. Because of the disruption of shoreline current flows, these structures turned out to be ecologically harmful and are no longer being constructed. From the mid-1990s, some shoreline campsites were constructed with kidney-shaped plans that minimized the disturbance to the current patterns but with vertical outer walls that eliminated the natural shoreline habitat. A more recent approach has been to add to the vertical walls a layer of local basalt rocks sloping into the water thus creating spawning sites and refuge for fish.

By law, a 50-m belt of shoreline around the lake, above the maximum water level of −209 m, belongs to the public. Thus, a public access walking path encircling the lake is being developed not without considerable controversy due to the many buildings that have been illegally constructed within the 50-m zone during the past decades.

Permissible limits for lake water levels: With the growth of Israel's population, the need to supply freshwater increased with time and the volumes of water supplied from Lake Kinneret via the NWC became greater than the annually renewable amounts (i.e., the total inflows minus the loss to evaporation). This demand led to a policy of reducing the permissible minimum water level in order to increase lake storage capacity. As a result, the mandatory minimum permissible level was lowered from −212 to −213 m in 1981 and then again to −215 m in 2001; increasing the potential amplitude of water level fluctuations to 6 m. The lowest-ever water level, −214.87 m, was recorded in November 2001.

New water from desalination: Israel's chronic shortage of freshwater led to a government decision in 2005 to supplement the country's natural supplies by very significant amounts of desalinated water. By 2015, it is envisaged that about 30% of Israel's water requirements will be supplied by desalination. As a result of this policy, the dependence on Lake Kinneret as a supply source of drinking water is decreasing. Since 2012, the stated aim of the Israel Water Authority has been to return the operational water levels of Lake Kinneret to between −209 and −213 m.

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