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Water Composition, Biomass, and Species Distribution of Vascular Plants in Lake Agmon-Hula (LAH) (1993–2023) and Nearby Surroundings: A Review

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Abstract: A significant change to the land cover in the Hula Valley was carried out during the 1950s: A swampy area densely covered by aquatic vegetation and the old shallow lake Hula were drained. The natural shallow lake and swamps land cover were converted into agricultural development land use in two stages: (1) Drainage that was accomplished in 1957; (2) Implementation of the renovated hydrological system structure, including the newly created shallow Lake Agmon-Hula (LAH), was completed in 2007. The long-term data record of the restored diversity of the submerged and emerged aquatic plant community, and its relation to water quality in the newly created shallow Lake Agmon-Hula LAH, was statistically evaluated. Internal interactions within the LAH ecosystem between aquatic plants and water quality, including nitrification, de-nitrification, sedimentation, photosynthetic intensity, and plant biomass and nutrient composition, were statistically evaluated. The plant community in LAH maintains a seasonal growth cycle of onset during late spring–summer and dieback accompanied by decomposed degradation during fall–early winter. The summer peak of aquatic plant biomass and consequent enhancement of photosynthetic intensity induces a pH increase during daytime and carbonate precipitation. Nevertheless, the ecosystem is aerobic and sulfate reduction and H_2S concentration are negligible. The Hula reclamation project (HP) is aimed at the improvement of eco-tourism's integration into management design. The vegetation research confirms habitat enrichment.

Keywords: Hula Valley; Lake Agmon Hula; aquatic plants; nutrient distribution

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1. Introduction

The Anthropocene Era describes an epoch when anthropogenic activity has potentially affected climate and ecosystem structure and dynamics as well as the distribution of aquatic vegetation. Throughout the Anthropocene, the Hula Valley and Lake Kinneret are a compatible interlock of Anthropogenic achievement in the national economy, water supply, agriculture, nature protection, and tourism management where terrestrial and aquatic plant distribution is a critical component. Therefore, integration between Anthropogenic involvement and natural floral and faunistic communities' structure and dynamics within the Hula Valley ecosystem has always been and is presently a continual subject for scientific and management design research. Future prediction requires knowledge about the role of man-made and natural change individually. On one side of the ecological issue, there is natural control of climatological, hydrological and nutrient dynamics conditions. On the other side of the ecological issue, there is Anthropogenic intervention. The newly created shallow Lake Agmon-Hula (LAH) ecosystem is comprised of environmental factors that are ecologically flexible and, therefore, induce significant changes. The species and density distribution of terrestrial, aquatic, and riparian plants in the Hula Valley after the drainage was intensively studied [1–11]. During the early 1990s, shortly after the LAH construction, a dense and unusual outbreak of growth of Cattail vegetation was documented. A misleading causation reason of sulfide toxicity was suggested, whereas globally documented lethal concentration is 100–1000 times higher than that was found and the phosphorus availability factor was neglected [12,13]. Moreover, the precaution of phosphorus enhancement in Lake Agmon-Hula (LAH) was attributed to migratory cranes' overnight stay there. Nevertheless, phosphorus fluctuations indicated enhancement during cranes' absence and the growth production of submerged vegetation was "blamed". The present paper emphasizes the ecological significance of biomass and nutrient contents in the submerged plants in LAH. The short history of LAH includes the HP constructions (1993–2006) and, onwards, agricultural maintenance periods. The aquatic vascular plant distribution in LAH and its close vicinity is a key factor for further management design of Hula Valley.

2. Study Site and Methods

Two geographical regions are focused on in this paper, Lake Kinneret and its drainage basin (2730 km^2 of which comprises the Hula Valley (200 km^2 between 60–180 masl)) (Figure 1).The uniqueness of the Lake Kinneret drainage basin and, specifically, the Hula Vally, is the meeting zone of northern and southern zoogeographical zones. A highly rich floral and faunistic biodiversity, with elements of flora and fauna, can be found. Until 1957, the Hula Valley was covered by the shallow Lake Hula (1.5 m mean depth; 1300 ha water surface), and 4500 ha of land permanently and seasonally covered by dense vegetation swampy wetland. From 1950 to 1957, the Hula Valley was drained and the land use was converted into agricultural development. A reclamation project, the Hula Project (HP), (1993–2007) included, among other constructions, the newly created shallow Lake Agmon-Hula (110 and shrunk later to 820 ha) was implemented. The most northern top of the drainage basin is 2814 masl, located 61 km from Lake Kinneret (210 mbsl), creating a mean slope of 5%. Three headwaters, Hatzbani (130 × 10^6 m^3/year), Banyas (app. 115 × 10^6 m^3/year), and Dan (app. 260 × 10^6 m^3/year), flow from north to south, crossing the Hula Valley and joining in the River Jordan (app. 200–800 × 10^6 m^3/year). From the Hula Valley (61 masl), River Jordan flows 15 km south into Lake Kinneret (210 mbsl). A very high variability of soil properties was indicated in the Hula Valley, as well as versatile species and land-cover plant composition and a hydrological-structure ecosystem. The post-drainage, newly created ecosystem's function was aimed at the development of agricultural land utilization. However, a comprehensive summary of temporal vegetation communities was not yet completed. This paper is a tentative assessment aimed at filling this missing link in the documentation of Hula Valley environmental research. The agricultural management that was carried out immediately after drainage suffered from a lack of experience and was therefore inappropriate. This paper is an attempt at an insight into the relations between nutrient concentrations and plant vegetation in LAH.

A routine sampling program accompanied the implementation of the Hula Project (1994–2006) and onward. The focus of the data sampling was aimed at water nutrient concentrations and species and biomass distribution of submerged and emerged vegetation. The sampling program accompanied the HP implementation on a weekly basis whilst, after 2006, intervals became longer. The data record presented in this survey continues from 1993 until present. The information about species and biomass distribution of aquatic and semi-aquatic submerged and emerged plants in the Hula valley, particularly in LAH, and nutrient content in the LAH waters, was documented in annual reports [1–11]. Regarding sampling methods, species diversity, biomass distribution, and nutrient contents of aquatic vegetation in LAH were sampled monthly in 12 stations and nutrient contents (Dry matter, Phosphorus, Nitrogen) were analyzed [1,6–10].

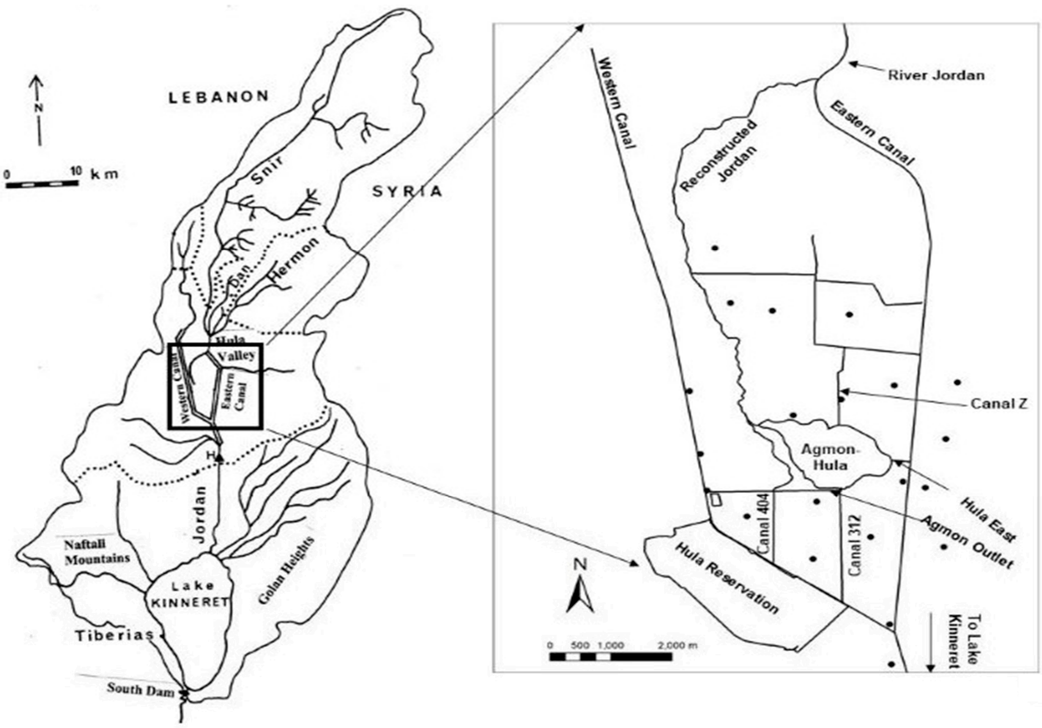


Figure 1. Geographical map of the Kinneret Drainage Basin (**left**) and the Hula Valley (**right**).

Statistical evaluation was performed using software of STATA 17.0-Standard Edition, Statistics and Data Science, Copyright 1985–2021 Stata Corp LLC, Stata Corp, 4905 Lakeway Drive, 4905 Lakeway Drive, 800-STATA-PC, Stata license: Single-user perpetual, Serial number: 401706315938, Licensed to Moshe Gophen, Migal. Four statistical methods were utilized: Linear Prediction with Confidence Limit of 95% (w/CL 95%); Quadratic Prediction (w/CL 95%); Lowess Smoother and Linear Regression.

The statistical method of two-way quadratic prediction (w/confidence interval 95%) is based on the standard error of the mean and utilized in this paper for the prediction of seasonal (monthly) changes (decline, increase, unchanged) of environmental parameters (physicochemical, nutrient concentrations) in the Shallow LAH; changes are recorded by month, and occasionally there is an estimated U-shape relationship. The results indicate that time (month) has a negative (decline) or positive (increase) impact or no impact on the parameter. The confidence interval indicates that if a parameter does not fit to month value in a certain range, the forecasted seasonal (month) value is reliable with 95% confidence.

Additionally, we used the statistical method of linear prediction (Linear Predictive Coding, LPC) w/95% confidence interval, where future values of discrete-time signals are estimated as a linear function of previously observed values.

These statistical methods properly characterize the temporal fluctuations of the two principal assembled data groups: the vegetation and the chemical composition.

3. Results

3.1. Species Richness and Biodiversity

The results given in Table 1 confirm the enhancement of plant species richness and biodiversity during the post-drainage period. This ecological change is attributed to the enhancement of varieties of terrestrial and riparian habitats, resulting from the drainage and the Hula Project implementation.

Table 1. Plant Species Richness is the number of plant species per 10^2 ha of the entire Hula Valley (SR), and Biodiversity Index (BD) is given as the ratio between plant species number and total species (plant, birds, fish) number; these were calculated for the periods before (B) and after (A) drainage.

Period	Value
B-SR	0.9
B-BD	0.15
A-SR	1.9
A-BD	0.26

3.1.1. Vascular Plant Species Richness (1994–2018) in and around LAH

Surveys carried out during 1994–2018 documented 147 plant species, including 35 invaders, of which 11 deteriorate local vegetation in LAH and the vicinity. The periodic increase in plant species number was 74, 115, and 115, during 1994–1996, 1996–2005, and 2008–2018, respectively [7,10,11].

3.1.2. Unwanted Plant Species

During the post-drainage period, which involved restoring agricultural crops and using imported corn seeds for crane-feeding management, the Hula Valley was an invasive plant destination. Anthropogenic induction exacerbated the invasion of 35 exotic plant species, of which 24 and 11 are regional and countrywide intruders, respectively [11].

3.1.3. Submerged and Emerged Macrophytes in LAH

Ten species of submerged and emerged high plants were recorded.

Submerged: *Potamogeton* spp. *Ceratophyllum*, and *Najas* spp.

Emerged: *Phragmites* sp., *Typha* sp. [5,10]. The total biomass (dw) and the content of phosphorus and nitrogen in plant matter were monitored monthly and the results are summarized in Table 2. The initiation of the aquatic vegetation onset usually occurs in April and peaks in July–August, and then the offset begins until dieback disappearance in December. Between December and April, the biomass is negligible.

Table 2. Peaks of aquatic vegetation biomass (tons DW) in the entire lake and P and N total contents (tons) during 1997–2004.

Year	Total Biomass (t dw)	Phosphorus (t)	Nitrogen (t)
1997	268	0.9	7.4
1998	213	0.7	6.3
1999	432	0.8	7.8
2000	343	0.9	6.6
2001	740	1.2	9.8
2002	817	1.2	9.8
2003	140	0.3	2.7
2004	698	1.1	10.5

The results given in Tables 2 and 3 conclusively indicate that the origin of most of the phosphorus in the Agmon-Hula outflow (1.2 t) is plant-mediated and approximately 50% of the nitrogen output is as well.

Table 3. Results of linear regression between chemo–physical parameters of shallow LAH water and two annual periods: (1) 1994–2006, Hula Project constructions; and (2) 1994–2023, stabilization of LAH size-restriction. r^2, p values, and statistical significance indication (S, NS) are indicated [1,3–5].

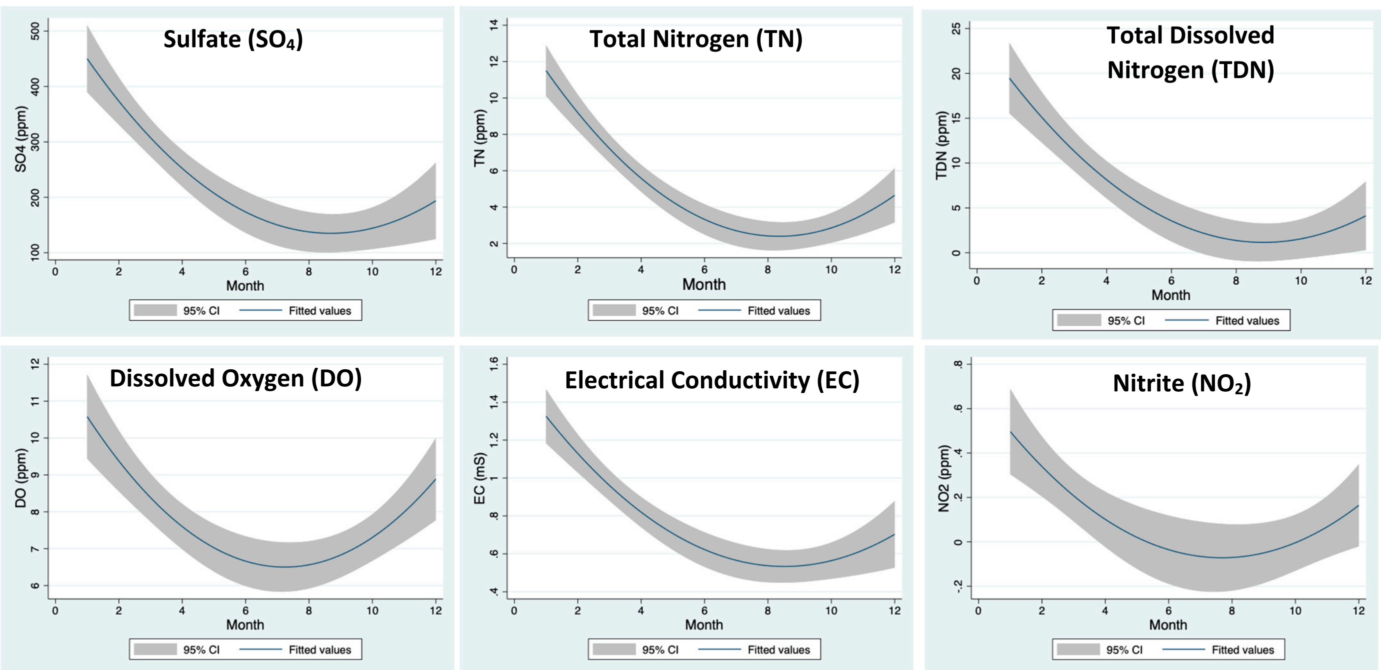
Parameter	Periodical Range	r^2	p (S) (NS)
TDS	1994–2006	0.2590	<0.0001 (S)
NTU	1994–2023	0.2104	<0.0001 (S).
EC	1994–2023	0.920	<0.0001 (S)
DO	1994–2006	0.1267	<0.0001 (S)
TP	1994–2023	0.0906	<0.0001 (S)
TN	1994–2023	0.534	<0.0001 (S)
ALK.	1994–2006	0.1972	<0.0001 (S)
SO_4	1994–2023	0.2014	<0.0001 (S)
NO_3	1994–2023	0.0194	<0.0001 (S)
pH	1994–2023	0.0250	<0.0001 (S)
NO_2	1994–2006	0.0784	<0.0001 (S)
TDP	1994–2023	0.0170	<0.0001 (S)
NH_4	1994–2023	0.0003	0.6974 (NS)
TDN	1994–2006	0.0003	0.8333 (NS)
TSS	1994–2023	0.0035	0.2231 (NS)

Common submerged and emerged plant species recorded in the Agmon-Hula were: *Potamogeton brechtoldii*, *P. crispus*, *P. pectinatus*, *P. trichoides*, *P. nodosus*, *P. senegalense*, *Najas minor*, *N. marina*, *Typha domingensis*, *T. latifolia*, *Phragmites australis*, *Arundo donax*, *Ceratophyllum demersum*, *Myriophyllum spicatum* [1,3–8,10,11,14–16].

3.1.4. Distribution of Nutrients and Physicochemical Factors Ion the LAH Waters

The results given in Table 1 indicate significant temporal fluctuations in nutrient concentrations. Regressions of ammonium, total dissolved nitrogen, and total suspended solids were insignificant.

Statistical plots of temporal (1994–2018) and seasonal (1–12) dynamics (annual and monthly mean) of the nutrient concentrations and physicochemical factors in LAH are presented in Figures 2–5.



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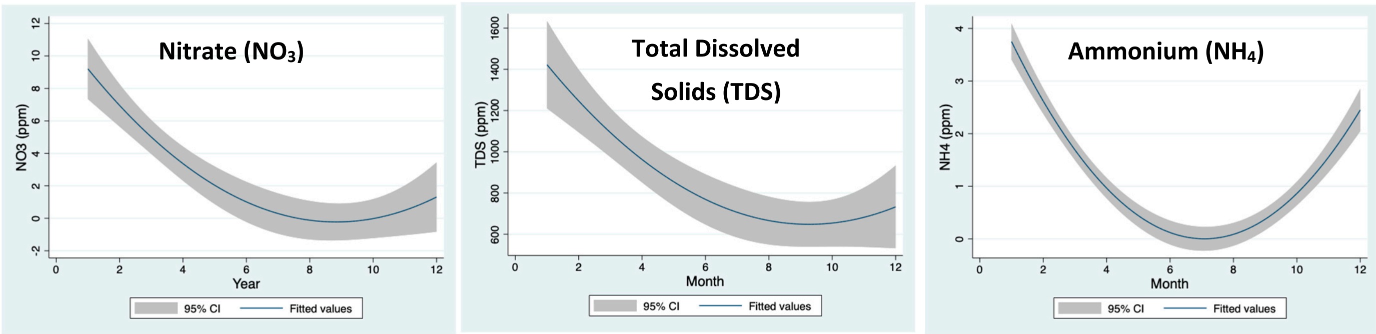

Figure 2. Two-way quadratic prediction relationship analysis between nutrient (SO_4, NO_3, TN, TDS, TDN, NO_2, NH_4) concentrations, EC, DO, and season (month) in LAH. Results indicate high values in winter and low values in summer followed by a moderately (distinctly shaper for ammonium) increased trend in fall–early winter. All plots represent moderate, and for ammonium, "deep", U-shaped relationships.

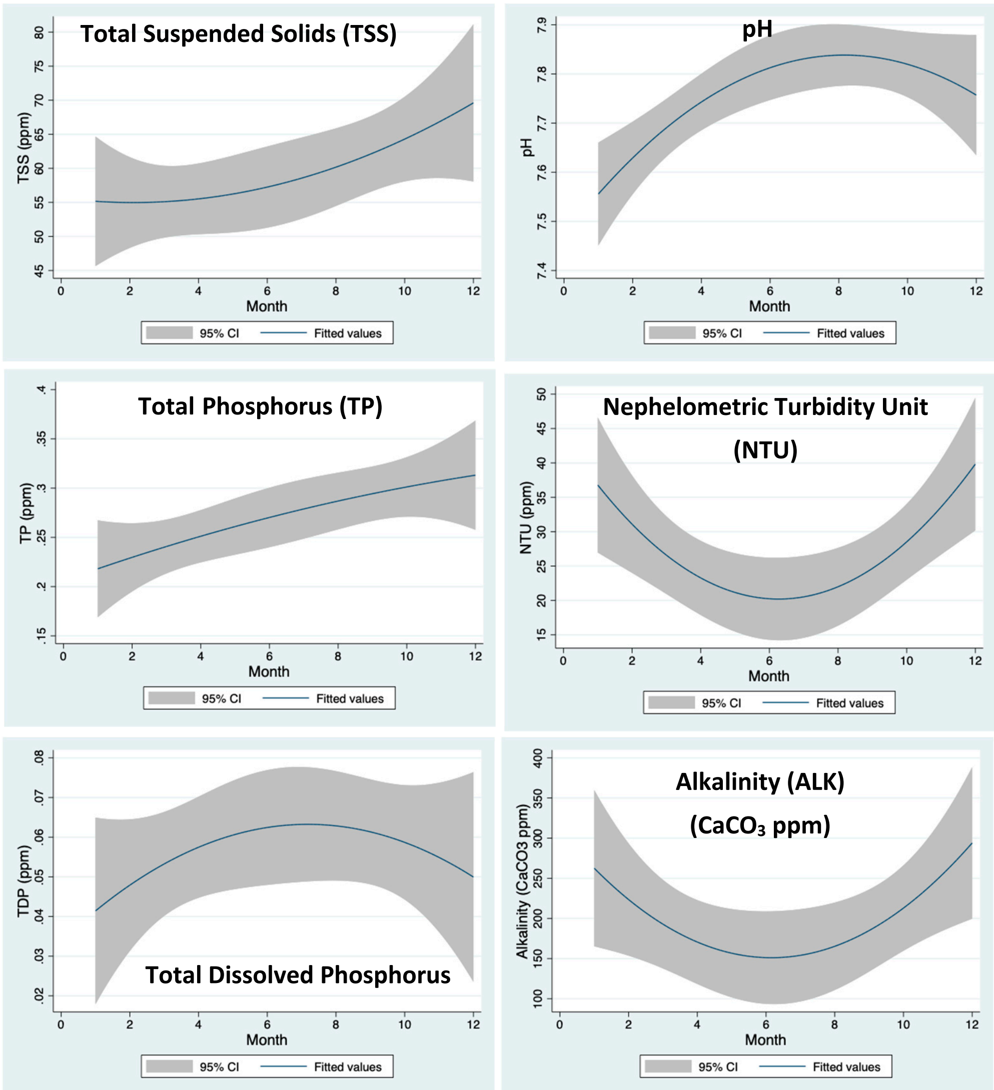

Figure 3. Two-way quadratic prediction relationship analysis between nutrient (TSS, TP, TDP,) concentrations, pH, NTU, ALK, and season (month) in LAH. Results indicate a high range of value variabilities and a summer increase of phosphorus (TP, TDP), pH, and TDS parameters whilst ALK and NTU represent U-shaped relationships with high variability.

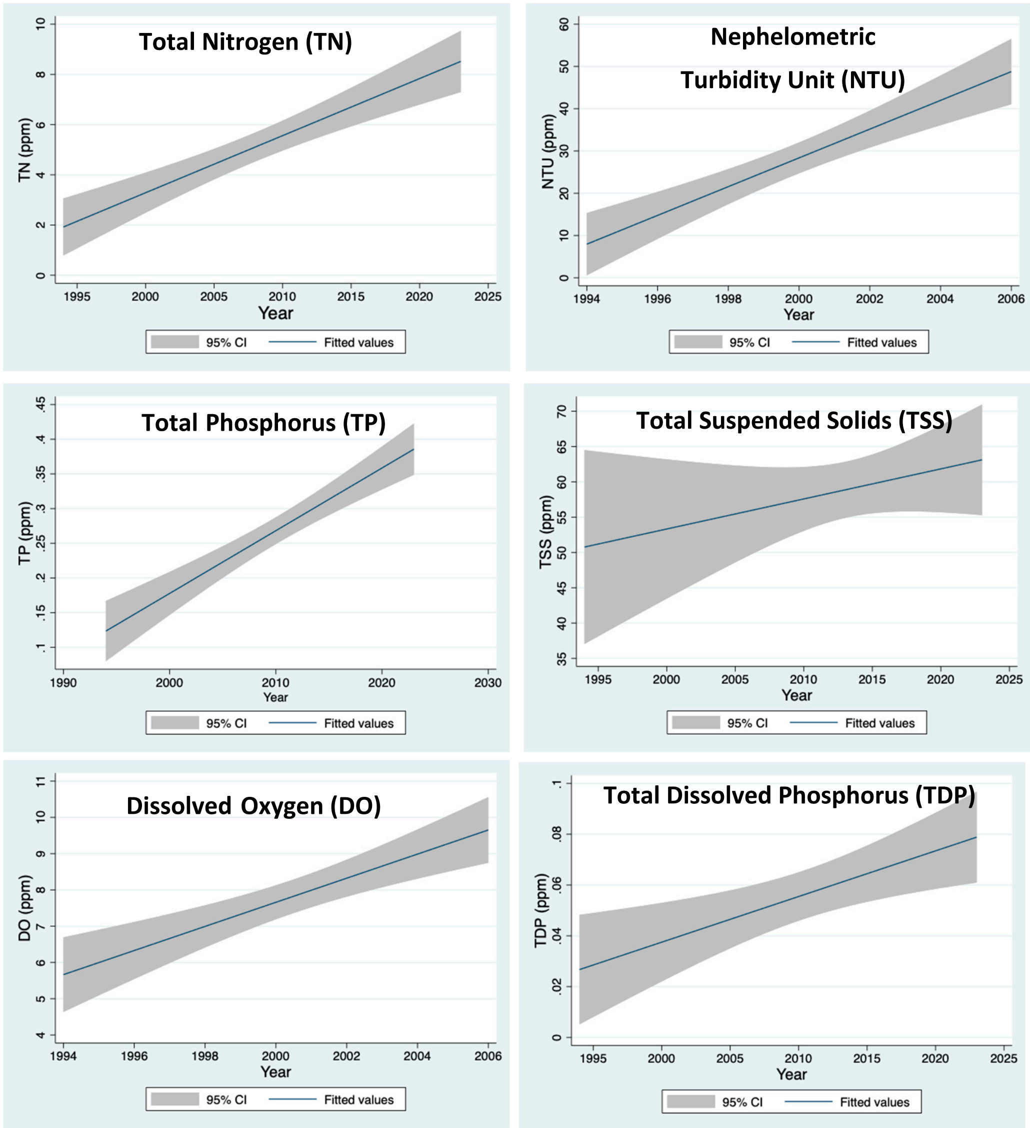

Figure 4. Plot of optimization of temporal (1994–2023) linear prediction (Linear Predictive Coding, LPC) w/95% confidence interval, where future values of discrete-time signals are estimated as a linear function of previously observed values of nutrients TP, TSS, TN, and TDP as well as DO and NTU during 1994–2023 in LAH. All nutrient concentrations and DO and NTU represent a trend of temporal elevation. A high range of annual variabilities of TSS is shown.

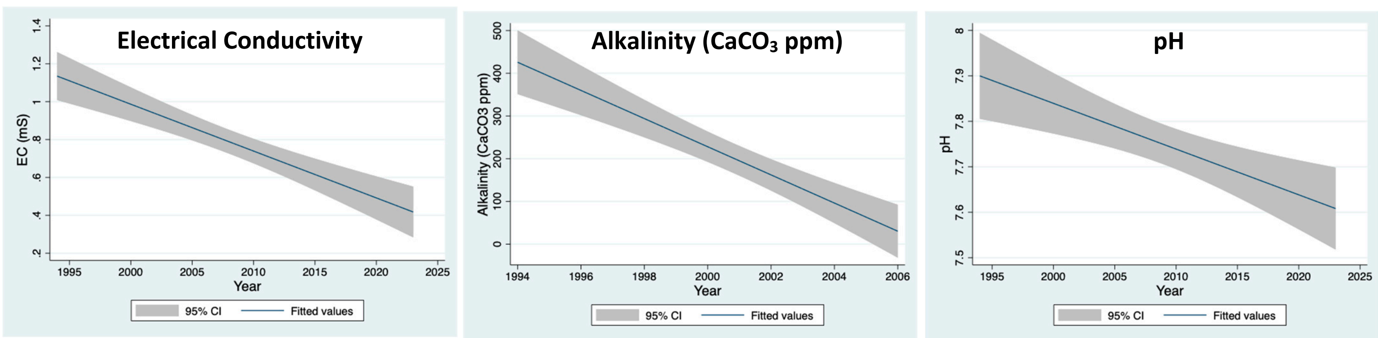

Figure 5. *Cont.*

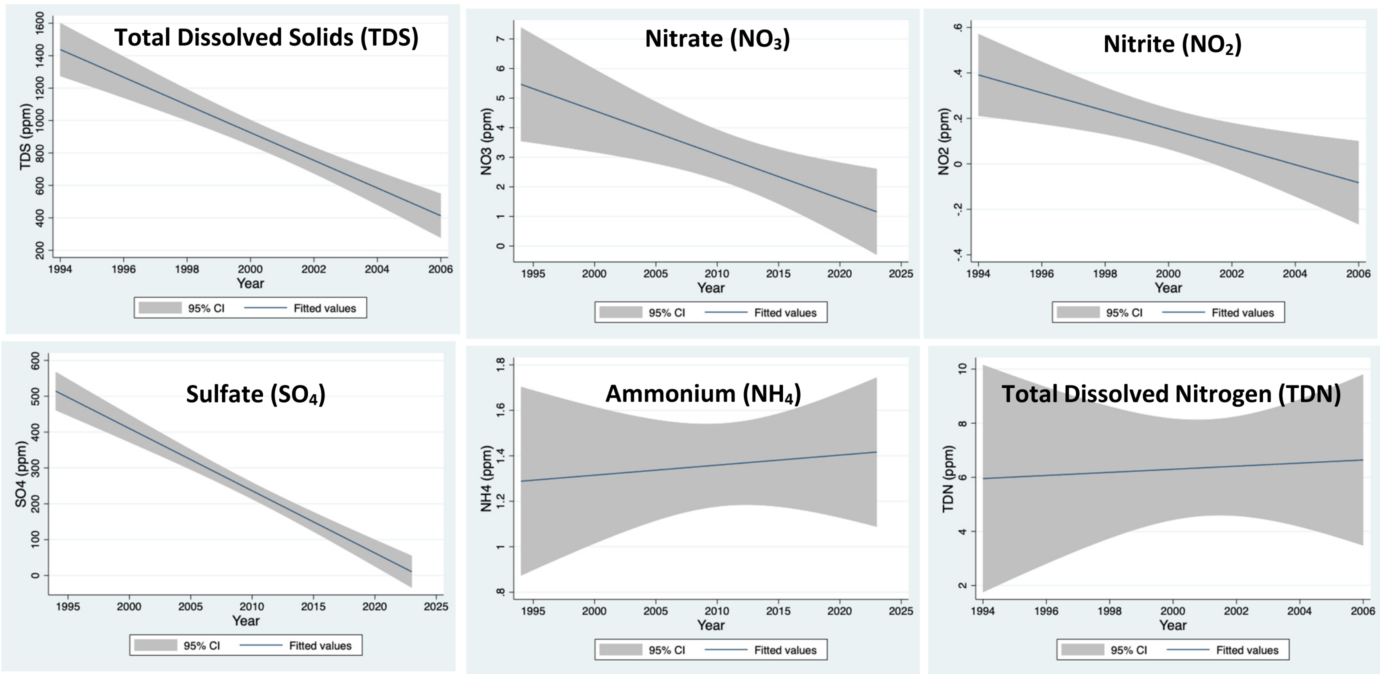

Figure 5. Plot of optimization of temporal (1994–2023) linear prediction (Linear Predictive Coding, LPC) w/95% confidence interval, where future values of discrete-time signals are estimated as a linear function of previously observed values of nutrients, TDS, SO_4, NO_3, NH_4, NO_2, during 1994–2023 in LAH. All nutrient concentrations except those for NH4 and TDN represent a distinct trend of temporal decline. A high range of annual variabilities, with no change of annual temporal trend for NH4 and TDN, are indicated.

4. Discussion

The floristic (terrestrial, aquatic, and riparian) distribution in the Hula Valley has been widely documented. Nevertheless, the documented results of earlier studies about facilitating interaction between nutrient availabilities and plant distribution are partial with regard to complicated ecosystem interactions such as those observed in Lake Agmon-Hula [9,17–25]. There are reciprocity interactions such as the mutual influence between plants' nutrient availability and physicochemical factors. The LAH ecosystem and the community structure of the flora in the Hula wetland, old Lake Hula, and the surrounding area prior to the drainage in the early 1950s were characterized by high diversity. This floristic composition resulted from phytogeographic meeting zones between Holarctic and Palaearctic speciation. The wetland habitat was predominated by thickets of *Cyperus papyrus* and the open clear waters by *Nymphaea alba* and *Nuphar lutea* [17,23]. The primary objective of the Lake Agmon-Hula creation project was nutrient collection and removal from the Kinneret input loads. An additional function of this lake is floristic restoration, although it is not a nature reservation site [6,10,12,26]. Environmental rehabilitation by the introduction of original plants was a targeted outcome. The introduction of several native species was carried out. The introduction of *Potamogeton pectinatus*, *Utricularia australis, and Marsilea minuta* was unsuccessful, whilst *Nuphar lutea* and *Butomus umbellatus* partially survived and *Nymphaea alba*, *Ludwigia palustris*, *iris pseudacorus*, and *Cyperus papyrus* flourished. Spontaneous intensive regrowth of submerged and emerged species was documented, including six species of *Potamogeton spp*. and two of *Najas* spp. [8,10]. It was found that the species composition and their relative aerial cover slightly fluctuated, whilst two species were permanently dominant, *Ceratophyllum demersum* and *Potamogeton nodosum*. Throughout the entire period, mid-water and bottom mats and floating scum lumps of filamentous algal matter were recorded. Eight plant species were documented throughout the study period in Lake Agmon-Hula, including *Potamogeton brechtoldii*, *P.*

crispus, *P. nodosum*, *Najas minor*, *Typha domingensis*, *Phragmites australis australis*, *and Ceratophyllum demersum*. Meanwhile, three species occasionally flourished, including *Potamogeton pectinatus*, *P. trichoides*, and *Najas minor.*

Land growth renewal of *Ludwigia stolonifera*, which created an invasion into the lake water, was observed through early summer (June). Clumpy thickets of *Phragmites. australis australis* were established and alternatively accompanied by *Typha domingensis*, and *Ludwigia stolonifera* densely covered the muddy bank bars along the lake shoreline. Those three species represented a slight trend of succession or potential instability. It is questioned if the rehabilitation of the flora in the re-flooded LAH is due to instability or success.

Conclusive remark: Periodical domination of 3–4 species in LAH, *T. domingensis*, *P. nodosus*, *Najas delilei*, and *Najas minor*, was documented. Recently, *N. delilei* disappeared, and *N. minor* became dominant among the submerged plants. The domination of *Phragmites australis*, *Typha domingensis,* and *Ludwiga stolonifera* probably resulted from the formation of muddy bars accumulation and/or the nutrient availabilities [7–11].

The study of ecosystem interaction between surface or pore water-mediated nutrient availability and aquatic plants' growth rates should consider their ecological properties. Phosphorus and nitrogen, for example, are subject to natural cycles or plant intake, whilst others are exposed to geochemical processes. The significant relationship between temporal and seasonal fluctuations of sulfate concentration indicates a relationship with soil moisture. Sulfate is a product of gypsum dissolution and, therefore, the higher the moisture, the higher its concentration (Figures 2 and 5). The major source of sulfate for Lake Agmon-Hula is soluble gypsum from peat soil. The majority of the sulfate is transported to the lake through peat soil drainage waters and a minority through advective flux through the bottom of the lake. Reduction of sulfate to sulfide is not predicted under aerobic conditions (Figure 4; 5–9 ppm DO) in the lake. Moreover, the impact of spring–summer moisture decline, followed by a lower range of carbonate and sulfate dissolution in the Hula Valley soil, results in lower input loads into LAH. The outcome of dryness is therefore temporal and there is a seasonal decline in SO_4, alkalinity (as $CaCO_3$ concentration), TDS, and electrical conductivity (Figures 2 and 5; Table 3). Nevertheless, a significant influence of those factors on the aquatic vegetation is not predicted. The hydrological management of LAH is aimed towards the prevention of anoxia, which, as of today, has never been recorded.

Unlike carbonates and sulfate, dissolved oxygen, (DO), pH, potential carbonate (calcite) precipitation, light penetration, and vegetation biomass are interlocked factors in a complex interaction community. The bottom sediments in Lake Agmon-Hula are organic decomposed plant material in the north and chalk-marl-carbonates rich in sulfate in the south. The LAH aquatic vegetation annual event is briefed in Table 2. An onset period, characterized by the proliferation of submerged plants, takes place late winter–early spring, peaks in August–September, then retreats, dies back, degrades and decomposes throughout September–December. A temporal (1994–2018) plot of DO concentration in the lake confirms long-term enhancement. It is probably (there are no data) the result of an increase in plant biomass. During 1994–2018, the lake surface was shrunk from 110 to 82 ha, and the mean depth from 0.5 to 0.2 m. Consequently, light penetration to the bottom of the lake was intensified, followed by the improvement of plant germination and growth conditions. Consequently, the biomass enhancement also enlarged the photosynthetic capacity of DO production (Figure 3). A potential factor that also supports the decline in DO concentration in spring and summer and its re-elevation in fall–early winter is the temperature (Figure 1). The dissolved coefficient of DO is temperature dependent. The decline in temporal and monthly values of pH (Figures 2 and 4) supported this hypothesis. Enhancement of photosynthetic activity is accompanied by an increase in CO2 uptake and an elevation of pH values. Moreover, the pH increase might be accompanied by an increase in carbonate concentration and a slight increase of EC (Figure 1) and precipitation (probably calcite), causing a summer increase of NTU and alkalinity values (Figure 2). The shrinkage of LAH by surface area, volume, and mean depth created conditions of increased turbidity

(NTU) (Figure 3). The temporal trend of the decline of SC, Alkalinity, pH, TDS, NO_3, NO_2, and SO_4 (Figure 4) is due to the dryness effect induced by the 2014–2018 drought period. Unchanged concentration levels of NH_4 and TDN (Figure 4) are probably the result of inappropriate internal ecological conditions of ammonification.

Plant-mediated nitrogen and phosphorus transfer from bottom sediments to the surface significantly affect the nutrients' concentration in the water in LAH. The submerged vegetation species in LAH develop shallow (several cm) root systems, whilst the root system of the emergent reeds is deeper. Consequently, nutrient availabilities in the bottom sediments probably differ for the shallow versus deep-rooted vegetation. It is therefore suggested that seasonal temperature and light-penetration factors and germination and growth rate of the shallow-rooted submerged plants are interdependent. The outcome of LAH depth decline was followed by vegetation biomass enhancement in springtime, and after the vegetation collapse in fall, the nutrient concentrations were significantly elevated.

Chemical and biogeochemical internal cycles and mass balances of nitrogen and phosphorus in LAH are different; however, both are adjacent soil moisture-related.

Mass budgets of P and N in LAH are dependent on external imports and internal cycles. The external sources of P are Hula Valley variable soil types, of which the peat is the major and dust deposition. Diffusive and advective sources through bottom sediment flux of P are negligible [27]. Nevertheless, the major contributing source of P within the LAH surface water is the decomposition of submerged plant biomass. This internal cycled trend of P channel initiates with exported soil particles, their sedimentation, and the uptake by plants through their root system, and is followed by their backward release as dissolved or particulate P when plant biomass is degraded (Figures 2 and 3).

The N dynamics include similar P stages of particulate-N and nitrate inputs, particle sedimentation, plant uptake, and degraded plant matter release. Nevertheless, internal N-input sources include also the ammonification of organic matter and the nitrification of ammonium under anoxic and aerobic conditions within the LAH ecosystem. Reduction of N concentration is supported also during the non-frequent anaerobic conditions through the denitrification process. It is suggested that the dominant factor is the external input of nitrate. The temporal decline of NO_3 migration from the peat soil resulted in precipitation decline followed by a decline in LAH, which is enhanced by denitrification and enhancement and summer decline. Enhancement of TP migration from the peat soil into LAH is due to summer dryness. It is supported in LAH by the seasonal degradation of submerged vegetation. The dynamic of P migration from Peat Soil is enhanced under low levels of moisture due to the geochemical properties of its linkage to peat soil particles. These geochemically bound types are more breakable under dry conditions. The drought period (2014–2018) enhanced P migration in the Hula Valley especially in the peat soil, followed by TP and TDP concentration increase in LAH improving growth conditions of aquatic vegetation. The increase of external P supply also enhanced phytoplankton productivity expressed indirectly as elevation of NTU values (turbidity) (Figure 3).

An exceptional case of the unusual intensive growth rate of Cattail (*Typha domingensis*) in the southern part of LAH was documented during 1993–1994. The flourished growth was suddenly terminated, collapsed, and never renewed at the same intensity. P content analysis in the sediments confirmed P limitation [13] whilst later experimental research based on the N/P ratio model has indicated N limitation as the reason and both studies rejected measured low (100–1000 times below literature accepted) concentration of H_2S toxication [28]. LAH was constructed in 1993 and the Cattail onset vegetation was immediately initiated. It is suggested that LAH constructive excavation activity exposed dry peat soil to aerobic conditions and the geochemical bound between P and organic matter within soil particles was broken, creating a trapped stock of available P. When the newly created LAH was filled with water, available P was incorporated by the Cattail developed vegetation. Within 1.5–2 years, most of this P stock was utilized and without compensated stock renewal, P limitation and dieback were implemented. The construction of LAH exposed the upper soil strata which were heavily loaded by cumulative Carbonate, Sulfate and other dissolved substances which were gradually flushed as shown for EC, Alkalinity, TDS, and SO_4 in Figure 4. Nutrient loading in LAH supplied to submerged and emerged vegetation was therefore carried out mostly by external support and partly through internal processes.

4.1. Conclusive Remarks

(1) This paper is focused on the ecological mutuality between aquatic vegetation and nutrient concentration and physicochemical parameters in LAH. The chemical, and physicochemical environmental conditions and aquatic vegetation in LAH are supplementary to each other.

(2) Nutrient concentrations in LAH have shown seasonal dynamics, where all except Phosphorus presented winter gradual decline and spring–summer elevation known as a U-shape distribution plot. However, Phosphorus concentration is represented throughout the winter season low level and increases continuity during the summer months. This seasonal distribution pattern overlaps similarity with the seasonal onset and dissipation of the submerged vegetation in LAH.

(3) The U-shape seasonal distribution pattern of NH4 represents an earlier start and higher summer increase than the other nutrient concentration dynamics. It is probably related to the impact of two contradicted nitrogen cycle processes, aerobic nitrification (enhances NO_3 and reduces NH_4) and anaerobic denitrification (reduces NO_3 and enhances NH_4). Moreover, the DO, NH_4, NO_3 and submerged vegetation distribution plots (Figure 1) where low levels of DO, NH_4 and MO_3 and the plant's high biomass simultaneously occur in summer (April–September).

4.2. The Winter System Composition

The gradual decline of DO and enhancement of denitrification aimed at the final product of volatile N2 which leaves to the atmosphere, NO3 and NH4 are therefore declining.

4.3. The Summer System Composition

In early summer, DO is enhanced as the result of plant photosynthetic production of oxygen, whereas onwards towards the second half of the summer, the plant biomass disintegrates and decomposes causing denitrification enhancement and, an increase of NH_4 accompanied by a very slight increase of nitrified NO_3.

(4) The concentration of external inputs of SO_4, and carbonates into LAH declines in winter because of Hula Valley soil wetting.

(5) The Hula Valley soil wetting enhances the migration of nitrogenic substances and reduces those of phosphoric matter.

4.4. Synopsis

The information presented in this reviewed document should be considered as a scientific infrastructure for management optimization of environmental ecosystems where natural and anthropogenic factors are integrated. Moreover, the key functioned role of the aquatic vascular plants' component in the management of wetlands habitat is emphasized.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The author declares no conflict of interest.

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