International Journal of
Environmental Sciences & Natural Resources
ISSN: 2572-1119

Juniper Publishers
key to the Researchers

Review Article
Volume 30 Issue 4 - June 2022
DOI: 10.19080/IJESNR.2022.30.556294

Int J Environ Sci Nat Res

The Impact of Ammonium Availabilty on Peridinium Blooming in Lake Kinneret (Israel): A Review

Moshe Gophen*

Migal, Scientific Research Institute, Israel

Submission: June 13, 2022; **Published:** June 23, 2022

***Corresponding author:** Moshe Gophen, Migal, Scientific Research Institute, POB 831 Kiryat Shmone (11016), Israel

Abstract

Since mid-1990`s the domination of the bloom forming Peridinium spp. was replaced by Cyanobacteria in Lake Kinneret (Israel). It is suggested that the efficiency of Nitrogen utilization by Peridinium is a dependent of ammonium availability. Furthermore, external supply of ammonium into Lake Kinneret is a dependent of anthropogenic management of the Hula Valley.

Keywords: Kinneret; Hula valley; Peridinium; Ammonium; Nitrate

Historical Highlights of the Hula Valley

The Kinneret drainage basin area is 2730km^2, located mostly to the north of the lake of which the Hula Valley is about 7% by aerial measures.Three major headwater rivers flow from the north (Hermon mountain region) to south and joint into one river Jordan. Jordan river contribute about 63% of the Kinneret water budget. Until mid-1950`s the Hula Valley was covered by swampy wetlands (3500ha) and old Lake Hula (1300ha). During 1950-1957 the Hula Valley was drained. Not much information was documented about the chemical composition of the Kinneret headwater, the Hula Valley wetlands and old Lake Hula before the drainage. Prior to the Hula Valley drainage (1957) about 40 scientific expeditions explored Lake Hula and surface waters in the Hula Valley and documented ecological information about it: name lists of fauna and flora and temperatures, pH, Chloride concentration, and Hardness of surface waters. Water quality as nutrient (Nitrogen, Phosphorus, Sulfide, Sulfate etc.) concentrations in the swamps and the old Lake Hula are not available [1]. Single documented analysis [2,3] reported about the presence of free and albuminoid Ammonia concentrations in the swamps and in old Lake Hula whereas Nitrate and Nitrite were reported as absent or below detection limit. The free and Albuminoid Ammonia concentration in the swampy waters was higher than in old Lake Hula was reported as well. Consequently, the reductive environment of the swamps is confirmed [1].

Land-Use Land-Cover Development in the Hula Valley

The indication of the Hula Valley as a wilderness was defined by the Mongolian (1240ac) and Malaria was introduced during the Crusader period (1099-1291ac). Enhancement of Water surface inundations of the swamps and old Lake Hula was resulted by the construction of Benot Yaakov bridge by Bivers in 1260. The major impact on human activity was due to the distribution of the Malaria disease. Settling of the Ghawarna nomad tribes in the Hula Valley was carried out during 1840-1948 while the nomad population increased from 520 to 31,470 residents. The regional populating management policy was no construction of permanent settlement housing in the Hula Valley. The agricultural management was defined as “the more dry was the winter more grass for cattle grazing and land for agriculture were available in spring-summer season”. The Jewish settlements in the Hula Valley initiated at the end of the 19th century and enhanced during the 1940`s. After the Hula Valley drainage the entire previously was old lake and wetlands area was converted into agriculture and 6900ha of natural wetland were converted to agricultural cultivation.

During 40 years agricultural products (Cotton, Corn, Barley, Wheat, Alfa – Alfa, vegetables, and others) were economically produced. As a result of inappropriate management, soil structure was deteriorated, the underground water table was deepened, gusty dust storms occurred, soil surface subsided 7-10cm/year, underground fires and rodent outbreak became frequent. A reclamation project was implemented (1994-2005).

The reclamation project included creation a new shallow Lake Agmon-Hula, (0.2m mean depth, and 82ha surface area) functioning as collector of nutrient effluents from the peat soil to be removed through the Agmon-Hula system out of the Kinneret watershed. Independently human domestic sewage and dairy-farming effluents removal projects were achieved. Collected sewage is transferred into treatment plants and stored in newly constructed reservoirs for irrigation reuse. During 1970-1985 fish-pods area in the Hula Valley was restricted from 1700 to 300ha. Sewage removal and fish-pond restriction eliminated significant load mass of nutrients, mostly organic nitrogen, and ammonium, from the Lake Kinneret external inputs. As a result of the drainage (1957) dominated nitrogen form that was contributed by the Hula Valley shifted from previously ammonium and organic nitrogen to nitrate. High and stable concentration of nitrate is presently represents continuously the major N-form in the effluents of the Hula Valley whilst N-organic and ammonium significantly declined. The ammonium and N-organic replacement by nitrate was the result of dryness and oxidation of the Peat soil after the drainage. The decline of N-organic and ammonium is attributed to sewage removal and diminished fish ponds.

Sewage Removal

As of 2007, 18 reservoirs with total volume of 4.1 10^6m^3 were constructed in the Kinneret watershed. Earlier, 12 $x10^6m^3$ of raw sewage entered annually into Lake Kinneret. During 1996-2007 total capacity of 83 tons/year TN (concentration ranged between 11-27ppm) were removed into reservoirs (data on ammonium is not available) whilst annual capacity of TN removed through the Agmon-Hula system (concentration ranged between 4.6-8.7ppm) varied between 11-48 ton/year. Removal of ammonium load (mean concentration 1.4ppm) through the Agmon-Hula system during 2000-2005 varied between 5.5-3.3 ton/y. Prior to the implementation of sewage removal project, in 1986, annual load of ammonium in the Jordan discharge was 70.2 tons whilst during 1999-2018 the mean capacity of ammonium in the Jordan was 21 tons, and the mean loads of nitrate was 718 tons. Consequently, ammonium removal from the Kinneret mass-balance through sewage treatment, as measured in the Jordan discharge is more efficient than through the Agmon-Hula system. Nevertheless, heavy loads of nitrates originated in the Peat-soil, enriched lake Kinneret TN standing stock. Before the drainage about 293 ton/y of free ammonia were delivered from the swamps into old Lake Hula and 117 ton/y of Albuminoid ammonia were forwarded from the old Lake Hula into the Jordan (annual discharge 650mcm, i.e., 10^6m^3) [1-3].

According to reported information [4,5] totally removed sewage volume was 7.2mcm (42%) out of the optional available storage capacity of 17.1mcm of which 1.6mcm were spilled over and 5.6mcm (33%) were reused for agriculture and therefore eliminated from the Lake Kinneret ecosystem. An average of 19ppm as the concentration of TN in the sewage removed into reservoirs indicates elimination of 106 tons of TN of which mostly is N-organic and ammonium. Prior to the Hula Drainage nitrates were almost absent [1-3] or negligible within the Jordan loads. Before drainage Jordan River conveyed 2.3 times more ammonium into Lake Kinneret than during 1985-1967 and 5.6 times more than during 1999-2018. After the drainage Peat soil oxidation was enhanced and nitrates became the major nitrogen form within the Jordan supply to Lake Knneret. Before sewage removal accomplishment the flux of N-organic and ammonium continue, for the benefit of nitrogen consumer demands (mostly Peridinium) in Lake Kinneret. After the achievement of sewage removal and aquaculture restriction loads of N-organic and ammonium declined and consequently the Peridinium bloom diminished.

Peridinium - Nitrogen Relationships in Lake Knneret

The Nitrogen demand by Peridinium for optimal growth rate was widely documented earlier [6-12]. Maximal concentrations of ammonium, in the Kinneret Epilimnion during the Peridinium Bloom season vary between 1.1-1.7µM which promptly decline later. Ammonium decline is due to algal uptake and microbial nitrification. Considering 3% of dry weight as nitrogen content in Peridinium cells and 40% as DW of Wet Weight and commonly documented peak of 150g(ww)/m^2 [8,11] the total nitrogen requirement to compensate the standing stock is about 30000 tons for the entire lake (168km^2 and 2000mcm, Epilimnion volume). Considering ammonium preferential uptake on Nitrate [13], the standing stock is insufficient. Therefore, the Peridinium preferential ammonium is a limiting factor although partly replaced by plenty of available nitrate. The high concentration of nitrate in early winter is due to the flux of nitrate and substantial bacterial nitrifiers originated from the Hula Peat soil [11]. The nitrogen sources supplied for the Peridinium bloom formation are mostly external although significant stock of Nitrogen is trapped in the bottom sediments [11,14]. The prominent decline of external supply of N-organic through headwater discharges (River Dan, River Jordan) since early 1980`s was documented [9,10]. Sewage removal and Fishponds restriction probably enhanced this trend of reduction. Similar decline was also documented in the Golan Heights Meshushim headwater discharge [9]. During late 1970`s and early 1980`s a prominent decline of nitrate at the expense of bacterial nitrification process. It was considered [10] as enhanced nitrate uptake by phytoplankters of which biomass was prominently increased. Nevertheless, simultaneous high concentration of ammonium was indicated as well. The optional uptake competition by Peridnium between ammonium and nitrate was not considered [10]. A worldwide well known tenet indicates that ammonium inhibits nitrate uptake [15] and low rate of nitrate uptake occurs when ammonium concentration

How to cite this article: Moshe G. The Impact of Ammonium Availabilty on Peridinium Blooming in Lake Kinneret (Israel): A Review. Int J Environ Sci Nat Res. 2022; 30(4): 556294. DOI: 10.19080/IJESNR.2022.30.556294

above 1μM and ammonium is preferred as nitrogen source although growth rates on nitrate continue [13,15,16]. Ammonium supply to the Kinneret Epilimnion in early winter is originate mostly from the Hypolimnion into the Epilimnion during de-Stratification which promptly decline while being oxidized to nitrate. The ammonium decline is attributed to algal uptake, and microbial nitrification. During the Peridinium bloom the Epilimnetic (app volume 2000mcm; 10^6m^3) ammonium mean concentration vary between 0.020 - 0.030 ppm (1.1-1.7μM) which is a total Epilimnetic stock of 40-60 tons. Standing stock of intracell nitrogen content within the Peridinium biomass is 30000 tons resulting ammonium insufficiency and nitrate is utilized instead. If ammonium concentration is higher than 1μM it is preferred but if lower - nitrate is incorporated. Prior to the sewage removal and aquaculture restriction ammonium supply probably compensated nitrogen demands by Peridinium. Later on when Nitrogen supply originate mostly from nitrate the Peridinium decline initiated. Prior to 1957 ammonium was efficiently supplied from the reductive swampy environment for the beneficial Peridinium bloom formation. Later on sewage and aquaculture became major ammonium suppliers and further on when major nitrogen source was nitrate the Peridinium declined. Nishri & Hamilton [10] considered direct relation between phytoplankton biomass and nitrates whilst competition and ammonium preference are not involved.

Conclusive Remarks and Future Perspectives

a) Hula Drainage initiated a shift from organic and ammonium nitrogen to nitrate supply which induced replacement of Peridinum by Cyanobacteria domination.

b) Long term process of nitrogen decline in the lake Kinneret Epilimnion induced the diminishment of Peridinium as confirmed by its seasonal renewal during heavy rainfall events and its local blooming along shoreline where decomposed vegetation enriched the nearby waters with N-organic and ammonium.

The design for long term Peridinium bloom renewal supportive ammonium and organic nitrogen supply by enhancement of anoxic kevel in Lake Agmon-Hula is recommended.

References

1. Dimentman Ch, HJ Bromely, FD Por (1992) Lake Hula, Reconstruction of the Fauna and Hydrobiology of a Lost Lake. Publications of the Israel Academy of Sciences and Humanities, p. 170p (Brief Summary in Hebrew p. 24).
2. Jones RF, Washbourn R (1940 a) Report of the Percy Sladen Expedition to Lake Huleh: A contribution the study of the Fresh - Waters of Palestine. -Part II. The Flora. J Bot Lond 78(936): 273-283.
3. Jones RF (1940 b) report of Percy Sladen Expedition to Lake Huleh: A contribution the study of the Fresh - Waters of Palestine. I. The plant ecology of the district. J Ecol 28(2)0: 357-376.
4. Meron M, M Peres, G Gershon, C Torchinski, R Alpert, et al. (2008) Upper Galilee Reservoirs Monitoring Program, Interim Report; (1996-2007), p. 36 *(in Hebrew).
5. Green P (2005) Annual Activity Report, Interim Report, (2004), p. 20(in Hebrew).
6. Gophen M (2015) The Impact of Available Nitrogen Deficiency on Long-Term Changes in the Lake Kinneret Ecosystem. Open Journal of Ecology 5(4): 147-157.
7. Gophen M, Smith VH, Nishri A, Threlkeld ST (1999) Nitrogen Deficiency, Phosphorus Sufficiency, and the Invasion of Lake Kinneret, Israel, by N2-Fixing Cyanobacterium Aphanizomenon Ovalisporum. Aquatic Sciences 1: 1-14.
8. Pollingher UT Berman, W. Rodhe, Serruya C (1978) Chapter: Peridinium: cinctum fa westii (Lemm) Lef. In: Lake Kinneret Monographiae Biologicae, Vol. 32, Junk Publishers, pp. 259-295.
9. Nishri A (2011) Long-Term Impacts of Draining a Watershed Wetland on a Downstream Lake, Lake Kinneret, Israel. Air, Soil and Water Research 4: 57-70.
10. Nishri A, DP Hamilton (2010) A mass balance evaluation of the ecologicxal significance of historical nitrogen fluxes in Lake Kinneret. Hydrobiologia 655: 109-119.
11. Serruya C, M Gophen, U Pollingher (1980) Lake Kinneret: Carbon Flow Patterns and Ecosystem Management. Arch Hydrobiol 88(3): 265-302.
12. Serruya C, Pollingher U (1971) An Attempt at Forecasting the Peridinium Bloom in Lake Kinneret (Lake Tiberias). Verhandlungen des Internationalen Verein Limnologie 19(1): 277-291.
13. Dortch Q (1990) The interaction between ammonium and nitrate uptake in phytoplankton. Marine Ecology Progress Series 61: 183-201.
14. T Zohary, U Pollingher, O Hadas, D Hambright (1998) Bloom dynamics and sedimentation of Peridinium gatunense in Lake Knneret. Limnology and Oceanography 43(2): 175-186.
15. Kanda J, DA Ziemann, LD Conquest, PK Bienfang (1990) Nitrate and ammonium uptake by phytoplankton populations during the spring bloom in Auke Bay, Alaska. Estuarine, Coastal and Shelf Sience 30(5): 509-524.
16. Smith JM, FP Chaves, CA Francis (2014) Ammonium uptake by phytoplankton regulates nitrification in the Sunlit Ocean. PLoS One 9(9): e108173.

How to cite this article: Moshe G. The Impact of Ammonium Availabilty on Peridinium Blooming in Lake Kinneret (Israel): A Review. Int J Environ Sci Nat Res. 2022; 30(4): 556294. DOI: 10.19080/IJESNR.2022.30.556294

DOI: 10.19080/IJESNR.2022.30.556294