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Experimental Study in Out-Door Tanks of N and P Uptake by the Aquatic Communities of Lake Kinneret

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Abstract

Two trials (1st Trial-46 and 2nd Trial-64 hrs duration) experiment in 8 out-door tanks (5 m^3) were carried out with similar design: 4 fish densities (0, 1, 5, and 10), 2 densities of zooplankton (high and low) and 4 increasing levels of P and N concentrations of nutrient enrichments. The consecutive changes of N and P concentrations were measured at 3 (Trial 1) and 4 (Trial 2) time intervals. It was found that nutrient uptake of the entire community, which is the differences between initial and final concentrations, was mostly affected by the initial enrichment. The ecological implications are discussed.

Keywords

Kinneret, N & P, Community Uptake, Zooplankton, Common Carp

1. Introduction

The research of nutrient uptake by zooplankton is a worldwide investigated issue. The majority of these studies were experimentally carried out under laboratory conditions. Nevertheless a move from isolated artificial small volume systems (jars, bottles, test-tubes etc.) to larger volumes is becoming more common. The usage of large outdoor tanks, shallow ponds, mesocosms and others for the study of nutrient uptake, or interrelationships between food-web compartments is commonly used in Marine and Freshwater ecosystems [1]-[5].

The epilimnetic biota of deep lakes is mostly comprised of three major components: phytoplankton (small and large size algae), zooplankton (micro and macro animals) and fish (large adults, small larvae and fingerlings). In Lake Kinneret the component of large body invertebrates is absent. The nutrient cycles, inputs and outputs as

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well as mass balances were intensively explored accompanied by long-term record of their availabilities. Moreover, indirect evaluation of nutrients utilization by plankton and geochemical transfer and losses were carried out and models were created. We studied the N and P uptake by the entire community in large volume facility (5 m^3 tanks) where three variables (zooplankton and fish densities and nutrient concentrations) were modified. Similar studies were also performed by monitoring of ecological variables in natural ecosystems. In this paper we present results of 46 and 64 hours experimental study of nitrogen and phosphorus uptake by the entire community (zooplankton, phytoplankton and fish). The experiments were carried out in out-door large tanks (5 m^3) and three levels of the variables: fish and zooplankton densities and nutrient (P and N) availabilities.

There are 24 fish species in Lake Kinneret of which 5 are exotics. The exotic Mugilids and Silver Carp are not reproduced in the lake and therefore annually introduced. *Oreochromis aureus*, and the Common Carp, *Cyprinus carpio* are reproduced in the lake and therefore not additionally introduced. The present existence of the latter two in the lake was resulted by old introductions which later totally stopped. The impact of the exotic fishes, excluding Common Carp, on the Lake Kinneret water quality was previously studied. The present study is aimed at both, N and P uptake indication accompanied by an attempt to evaluate potential effect of Common Carp on the Kinneret water quality. The Kinneret ecosystem structure has been modified and nutrient availabilities was shifted from P to N limitation [6] [7]. Consequently trophic relations between food-web compartment were modified [8]-[10].

2. Material and Methods

The experiments were carried out in eight 5 m^3 outdoor tanks directly supplied by Lake Kinneret waters (intake depth-1.5 m 100 m from shoreline). The tanks are equipped with compressed air lift aeration system. The experiments design is given in **Table 1**. The fishes were 100 - 150 g/Ind. of Common Carp (*Cyprinus carpio*). Two densities level (high and low) of Zooplankton were maintained. The lake density of large body zooplankton was about 50 per 1 liter. For the experimental addition we collected zooplankton in the open water zone (>20 m depth) of the lake, by down (15 m) and up 15 time hauls of 100 μ mesh plankton net with 25 cm diameter open mouth. The total quantity of filtered lake water was approximated as 2.5 m^3. Collected animals were carefully flushed from the net collector (bucket) into 20 L (lake water) pail and continuously mixed. One liter and 0.5 liter were removed from the pail while mixing into each of the experimental tanks with "High" and "Low" additional zooplankton respectfully. The initial zooplankton densities were approximated as 70 and 60 organisms per liter in the "High" and "Low" tanks respectively. The zooplankton addition was done separately for Trial 1 and 2 (**Table 1**). In order to emphasize temporal changes, 2 trials were carried out: the time duration of the 1st trial was 46 hours and for the second-64 hours. The two trials were carried out with similar fish number (densities) and the same individuals. The zooplankton was collected separately for each trial by the same procedure and time interval between the two trials was 3 days. Evaporated water loss was compensated by pumped lake water during the 3 days interval between trials. Additional nutrients were given initially to the tanks in 2 (Trial 1) and 3 levels (Trial 2). The nutrients initial concentrations in the tanks are given in **Table 2**. In the first trial, three samples were collected: (initial, 24 and 46 hours); in the second Trial-4 samples (initial, 41, 48 and 64 hours). Added nutrients were NH_4Cl and Na_3PO_4. Nutrients were added at three levels and their averages (SD) of all treatments for each sampling time (1st Trial-3, and 2nd Trial-4) are given in **Table 2** (Trial 1) and **Table 3** (Trial 2). Aeration was operated 2 hours during day time every 24 hours.

To determine concentrations of P-PO_4 and N-NH_4 we used analysis procedures given in [11].

3. Results

ANOVA comparative tests ($p < 0.05$) were carried out aimed at indication if there is an impact of zooplankton and fish densities and enrichment levels on the community uptake of nutrients. The uptake measure was considered as the nutrient concentration differences between initial and final time. Results of Trial 1 indicates: zooplankton and fish densities did not have significant impact (all p values were higher than 0.05) on the total (include: initial, 24 hr and 46 hr) averages of P-PO_4 and N-NH_4 concentrations. The only significant effect on community uptake of nutrients was that of enrichment levels. Similarly, in the 2nd Trial, the only significant ($p < 0.05$) impact on the total (including all samples) averaged concentrations of P-PO_4 and N-NH_4 was that of nutrient enrichments. Nevertheless, successive processes evaluation presented as a continuous figures plotting;

Table 1. Experimental design: zooplankton addition (H = High; L = Low) and fish number in the tanks.

Tank No.	Additional Zooplankton Level	Number of Fishes
1	H	0
2	L	0
3	H	1
4	L	1
5	H	5
6	L	5
7	H	10
8	L	10

Table 2. Three sampled (0, 24, 46 hours) averages (SD) concentrations of N-NH_4 and P-PO_4 in 8 tanks, and 3 levels of enrichment.

Nutrient	Enrichment levels (ppm)	Averaged concentration (ppm) (SD) of all treatments in three samples: 0, 24, 46 hrs
N-NH_4	1	0.599 (0.140)
N-NH_4	2	1.036 (0.169)
N-NH_4	3	1.554 (0.117)
P-PO_4	1	0.275 (0.023)
P-PO_4	2	0.522 (0.033)
P-PO_4	3	0.758 (0.103)

Table 3. Initial averaged (SD) concentration of N-NH_4 and P-PO_4 in 8 tanks of Trial 2 respective to enrichment level: 0, 1, 2 and 3. Original concentrations were: N-NH_4 = 0.1939 ppm and P-PO_4 = 0.0362 ppm.

Nutrient	Enrichment levels: 1, 2, 30.	Averaged concentration (ppm) (SD) of all treatments in four samples: 0, 41, 48, 64 hrs
N-NH_4	1	0.8178 (0.3026)
N-NH_4	2	1.3985 (0.2481)
N-NH_4	3	2.1352 (0.3636)
P-PO_4	1	0.2684 (0.0096)
P-PO_4	2	0.5369 (0.0202)
P-PO_4	3	0.8095 (0.0388)

several impact factors were indicated as follows:

Trial 1 (**Figures 1-4**): **Figure 1** indicates that as the initial concentration is increasing, the difference between initial and final (46 hr) time concentration is elevated proportionally too. This difference is a measure of biotic community uptake. The pattern of the changes of the difference between initial time and final time N-NH_4 vs initial time concentration of N-NH_4 changes is similar to those of P-PO_4 (**Figure 2**) but not higher than 1.0 ppm of the initial concentration when it is declining. It is not impossible that other processes are involved, such as geochemical oxygenation of NH_4 to be converted to nitrate, also took place. Especially affected by the daily 2 hours aeration in the tanks continuously. Nevertheless the impact of this factor and probably others, was the same in all tanks and therefore differences could be attributed solely to enrichments levels. Results in **Figure 2** indicate that not like the uptake of P-PO_4 (**Figure 1**) there is a decline of N uptake if initial concentration of NH_4 is above 1.0 ppm. Compatible results are presented in **Figure 3**: uptake of P increase while N intake increase up to a level below 0.2 ppm whilst the elevation of P uptake continued slightly. **Figure 4** is indicating the trend of uptake elevation of P and N respectively whilst **Figures 1-3** emphasize dynamical changes.

Trial 2 (**Figures 5-10**): Similar to the 1st Trial results presented in **Figure 5** indicates increase of N uptake with elevation of P uptake up to 0.1 ppm of NH_4 and decline afterwards. The positive relation between N and P uptake and enrichment levels is presented in **Figure 6** and **Figure 7** but P uptake slightly declined in the highest (3) level of enrichment. The interpretation of the slight decline of P uptake when N uptake is increasing above

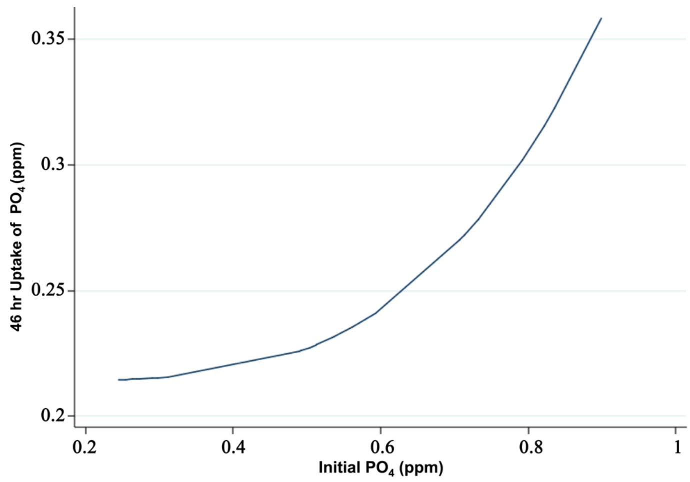

Figure 1. Trial 1: Fractional polynomial regression between initial PO_4 concentration (ppm) and consumed PO_4 (concentrations difference between initial and 46 hr).

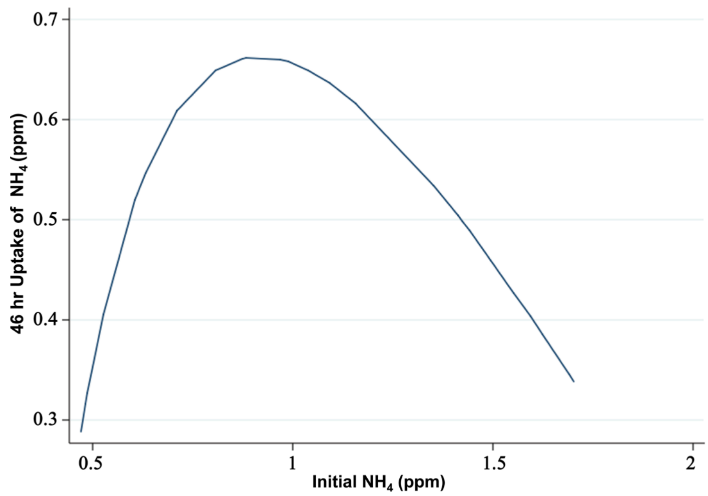

Figure 2. Trial 1: Fractional polynomial regression between initial NH_4 concentration (ppm) and consumed NH_4 (concentrations difference between initial and 46 hr).

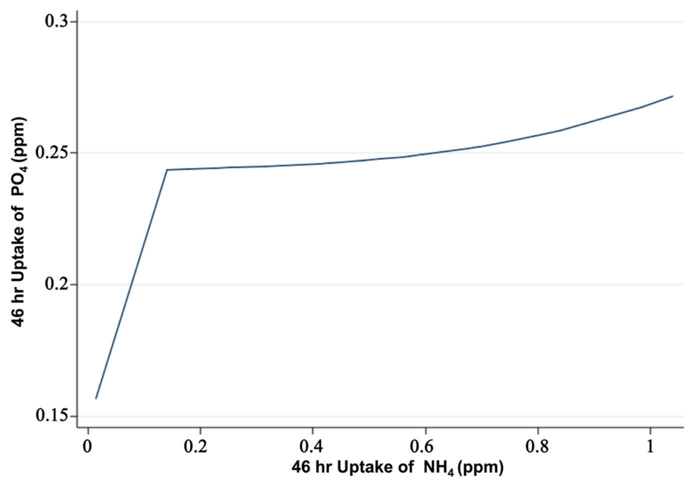

Figure 3. Trial 1: Fractional polynomial regression between consumed NH_4 and consumed PO_4 (concentrations (ppm) difference between initial and 46 hr).

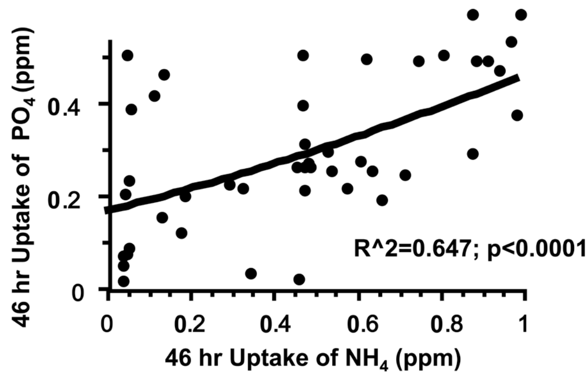

Figure 4. Trial 1: Polynomial regression (r^2 and p values are given) between total averages (Init., 24, 46 hrs) of NH_4 vs PO_4 concentrations (ppm).

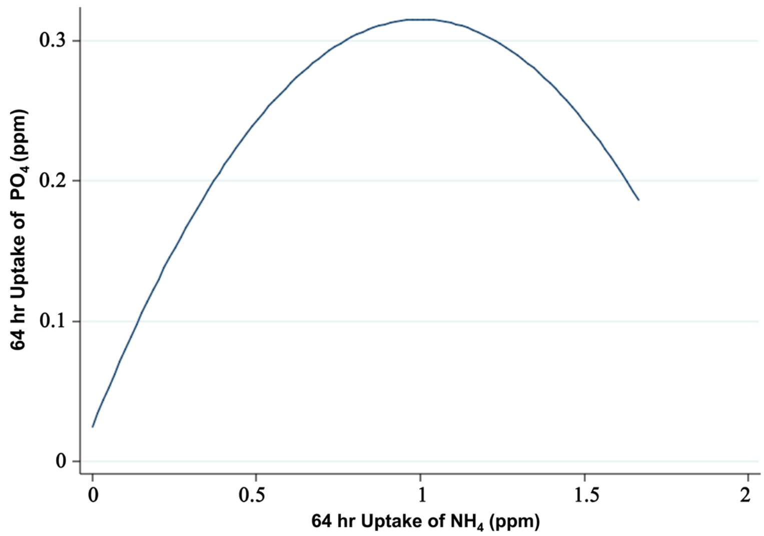

Figure 5. Trial 2: Fractional polynomial regression between consumed (initial minus 64 hr) NH_4 concentration and consumed PO_4 (initial minus 64 hr concentrations, ppm).

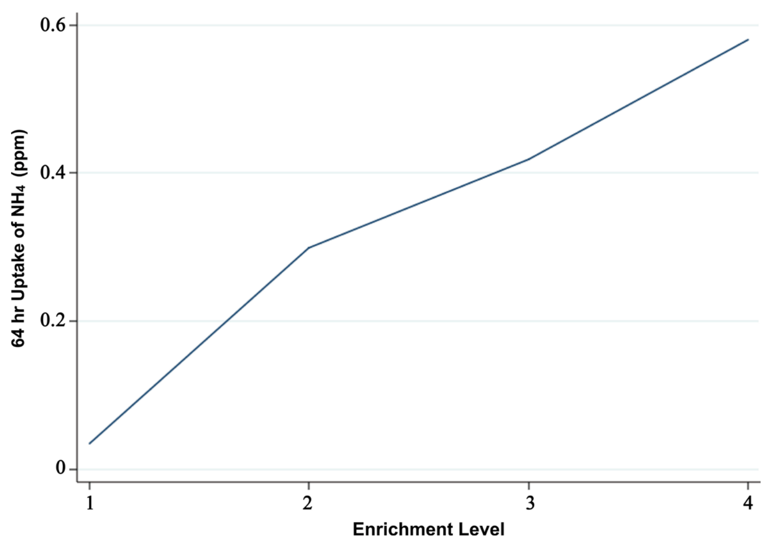

Figure 6. Trial 2: Fractional polynomial regression between four levels (1 - 4) of enrichments and consumed NH_4 (ppm).

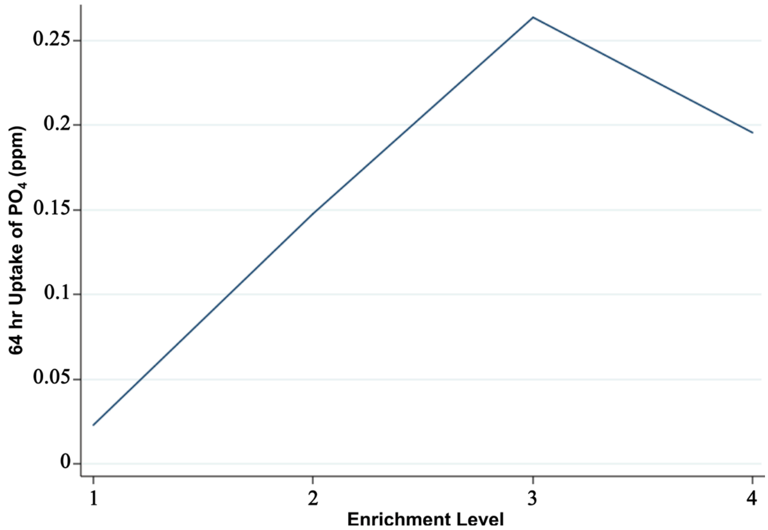

Figure 7. Trial 2: Fractional polynomial regression between four levels (1 - 4) of enrichments and consumed PO_4 (ppm).

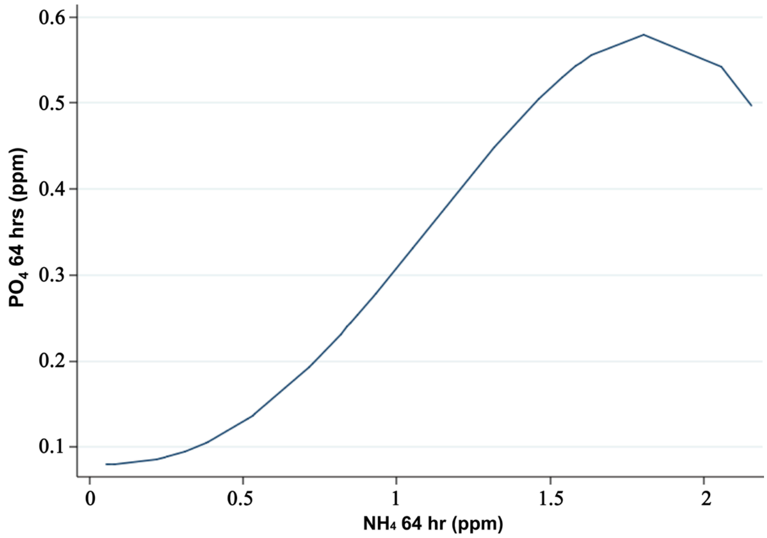

Figure 8. Trial 2: Fractional polynomial regression between 64 hr concentration (ppm) of NH_4 and PO_4.

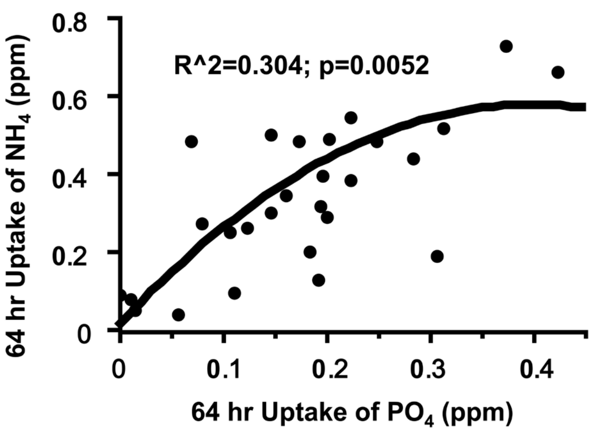

Figure 9. Trial 2: Polynomial regression (r^2 and p values are given) between consumed (Init. minus 64 hr concentrations, ppm) of NH_4 and PO_4.

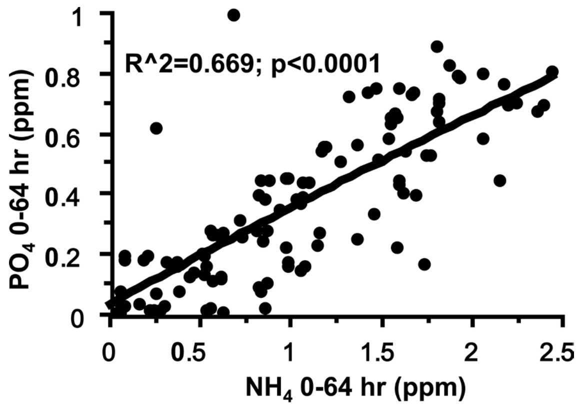

Figure 10. Trial 2: Polynomial regression (r^2 and p values are given) between total averages (Init., 41, 48, 64 hrs) of NH_4 vs PO_4 concentrations (ppm).

1.5 ppm (**Figure 8**) is probably an indirect confirmation of stoichiometric regulation (homeostasis) of nutrients uptake [12] [13]. The overall comprehensive simultaneous increase of P and N uptake is shown in the regressions presented in **Figure 9**, **Figure 10**.

4. Discussion

The use of nutrient concentration as a measure for community uptake was documented worldwide in aquatic research [14]-[19]. The uniqueness trait of the experimental design presented in this paper is an achievement of experimental structure simplicity by the usage of low number of variables. The outdoor tanks dimensions, the initially usage of lake water composition (chemical and biological) and the aeration procedure and regime were all the same in the tanks. The only independently dissimilar variables between tanks were: nutrient enrichments, zooplankton and fish densities. Several ecological factors were a priori accounted as similar in all tanks: light and temperature conditions, nitrification and de-nitrification processes, photosynthetic activity, and Diurnal Vertical Migration (DVM) of plankton. The focus is given in this paper to the community uptake of N and P nutrients. The ecological conditions (parameters) in the tanks were considered as similar except nutrient concentrations (enrichments), and fish and zooplankton densities. Therefore evaluations of temporal changes (days) were done on these parameters only. Results indicated temporal dissimilarities of community uptake rates of nutrients. The changes of nutrient uptake rates were prominently dissimilar at the final stages of the two trials. Due to the differences in zooplankton and fish densities, variability of N and P consumption were predicted. There are two methods for the analysis of the temporal changes of community consumptions of nutrients: 1) regressive relation between averages and time intervals or in-between nutrients; and 2) regressive relation between continual consequent changes of the parameters of the studied variables with time and in between nutrients. In our study, the 1st method resulted similarity between nutrients, on the other hand the 2nd method represented only partial similarity. This later dissimilarity was termed by scientists as homeostasis or stoichiometric regulation. It was indicated that during low level of N and P concentration, the uptake of both is maintained simultaneously whilst when N is increasing higher P uptake relatively decline [6]. Significant impact on this was only due to the variable changes of P and N concentration ("Enrichment" in our study) but not zooplankton and fish densities within the frame of the present study. The fish densities in this study were ranged between 20 - 200 g/m^3 whilst the averaged lake density is approximated as 2.5 - 3.5 g/m^3. The experimental densities did not affect significantly, indirectly or directly, the nutrient uptake regime. The nutrient uptake by biota in the tanks was represented by the left-over of subtraction of the final from initial time concentration. This value represents an overall change where several processes are involved. Nevertheless, the impact of fish and zooplankton densities was found to be an insignificant differ, and it is probable that their effect in all tanks were similar. On the contrary, the impact of nutrient concentrations was significantly dissimilar between tanks. Stoichiometric regulation of N and P uptake in fish is not well known as in zooplankton. Therefore, it is conclusively suggested that zooplankton homeosthasis is involved in the present study conditions. Limiting nutrients are utilized for growth at high efficiency whilst non limiting elements must be therefore disposed off or recycled [12] [13]. Hessen [12] stated that there is a tradeoff between metabolic demands of P and the dietary deficiencies of P and/or N. Zooplankton consumption (uptake/excretion) of P and N in Lake Kinneret resulted nutrients turnover time of 8 and 2 days for N and P respectively during summer-fall season [20]. Time durations of the two trials presented here were 1.9 (1st Trial) and 2.6 (2nd Trial) days which are both shorter (equal for P in 2nd Trial) than those measured for N and P in the lake by Rachamim [20]. The potential impact of fish on the nutrients availabilities can be evaluated through their densities in the tanks in comparison with lake conditions. Fish densities in the tanks varied between 20 - 200 g/m^3 whilst fish stock in the lake is approximately ranged between 2.5 - 3.5 g/m^3 and Zooplankton concentration—3.5 - 4.5 g/m^3. According to the procedure of zooplankton collection by net hauls it can be approximated that its densities in the tanks was slightly higher than in the lake and turnover time of both N and P was therefore shorter than measured by Rachamim [20] under natural conditions in the lake. Consequently it is suggested that recycled elements partly supported N and P for zooplankton requirements. The results documented in the present study does not confirm impact of the Common Carp densities ranged between 20 - 200 g/m^3 on the Kinneret water quality within the time exposure of 46 - 64 hours. Similar conclusion is also attributed to the ranged densities of zooplankton (high and low) and time duration that were examined in the present research.

5. Summary

Experimental study of the impact of fish and zooplankton densities and nutrient concentrations on N and P community uptake was carried out in 5 m^3 out-door tanks. Two trial durations were tested: 46 and 64 hrs. It was found that increase of initial concentration of N & P was accompanied by increase rate of community uptake of those nutrients. When community uptake of N increased, respective elevation of P consumption was documented but not above 0.2 ppm of N. Then P consumption was increasing irrespective (lower) to N uptake. Moreover, when initial concentration of N increased above 1 ppm, community uptake of N declined. Statistical results analysis indicates significant impacts of initial nutrient concentrations and insignificant effects of zooplankton density level (experimental "High" and "Low") and fish densities ranged from 20 to 200 g/m^3.

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