Scientific Research Publishing

Open Journal of Modern Hydrology, 2017, 7, 1-10
http://www.scirp.org/journal/ojmh
ISSN Online: 2163-0496
ISSN Print: 2163-0461

Experimental Study of the Feeding Habits of *Tilapia zillii* (Gervais) in Lake Kinneret

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How to cite this paper: Gophen, M. (2017) Experimental Study of the Feeding Habits of *Tilapia zillii* (Gervais) in Lake Kinneret. *Open Journal of Modern Hydrology*, **7**, 1-10.
http://dx.doi.org/10.4236/ojmh.2017.71001

Received: January 1, 2017
Accepted: January 22, 2017
Published: January 25, 2017

Abstract

The feeding habits of the cichlid *Tilapia zillii* (Gervais) in Lake Kinneret (Israel) were experimentally studied in indoor glass containers (2.5 hrs) and two trials in outdoor 5 m^3 tanks (20 - 25 days). The trait of food particle collection by adult fishes was measured. A survey was carried out in the littoral (0 - 1.0 m deep) zone and fingerlings were sampled by electro-chocker. The gut content of the fingerlings was analyzed. The feeding habits of *T. zillii* were indicated as planktivorous filtration with more enhancements of small zooplankters (Nauplius, Brachionid rotifers) and fewer of Cladocerans suppressions.

Keywords

Tilapia zillii, Kinneret, Feeding, Ecological Adaptation

1. Introduction

Fish feeding habits and food particle selectivity are known to be correlated with their actual habitat or their geo-ecological origin. Nevertheless, natural ichthyofaunal diversity initiates food resources partitioning, and the ecological structure of Lake Victoria is a well known versatile system. The original fish community of Lake Kinneret includes 19 species from three primary and four secondary freshwater originated families [1]. Three exotic species which are annually introduced comprise a significant part of the Kinneret Ichthyofauna. From the Zoogeographical viewpoint, 6 species are Paleoarctician, 9 species are Ethiopian, and 4 species are Endemic [1]. It was suggested that Tilapias were originated in marine ecosystems and migrated into freshwater habitats [2] [3] [4] [5] [6]. Consequently, euryhalinity in many of the Tilapia species is known worldwide [7]. Several Tilapia species (*T. guineensis*, *S. melanotheron*, *O. mossambicus*, *O. hornorum and O. placidus*) are highly tolerant to salinity levels of up to 30 ppt populate and reproduce in estuaries and lagoons along Western and Eastern African coasts [7]. Nevertheless, the natural reproductions of only two species (*O. mosammbicus*, *T. zillii*)

were reported in seawaters [8] [9] [10] [11]. In the saline (29.4 ppt) Lake Quarun, Suez Bay (43 ppt), and Bardawil Lagoon (41 - 45 ppt), Egypt, adult (not fingerlings) *T. zillii* is the only common Tilapia that exists [8] [11] [12]. Studies on food composition of *T. zillii* in nature and cultured were previously carried out [5] [13] [14]. Nevertheless, the habit of food item collection was not yet widely reported. The aim of the present study is to clarify food item selectivity as well as characterization of natural preference of salinity. *T. zillii* is able to change its appearance by melanistic-marking pattern [15]. It was concluded that those melanistic variabilities, as also documented in other cichlids, were resulted by stressors such as attack-escape, darkening, territorial and spawning but not feeding behaviour. Therefore, the idea of the existence of more than one species of *T. zillii* in Lake Kinneret cannot be confirmed presently and DNA structure is required. With regard to food availability, the resource partitioning is critical [16]. If the food resource usage is different between coexisting planktivore Tilapia species in Lake Kinneret, particle selection in the multi-species experimental system might give the answer. The practical expected implicated objectives from the study are focused on the understanding of the process of adaptation of *Tilapia zillii* within the Kinneret ecosystem as background of water quality and fishery managements design.

2. Material and Methods

2.1. Glass Indoor Containers Experiment

The Glass container experiments design was as follows. The experiment was carried out in five 120 L glass indoor containers (Aquarium), each containing 112 L of filtered (63 μ mesh size net) lake water under ambient indoor conditions: diffused light; 23˚C - 26˚C stable room temperature. *T. zillii* specimen were placed (**Table 1**): 1 fish in each of containers 1, 2 and 2 fishes in containers 4 and 5, and 1 fishless container.

Fishes were introduced into the containers with filtered lake water two days before experiments started for acclimatization. Fresh plankton was collected in the lake containing 63 μ mesh size plankton net and re-suspended in lake water. The same aliquot of fresh plankton suspension was given to the fishless and each other container. Samples were collected in the containers immediately after the insert of the plankton suspension (Initial time) and 2.5 hours later. The containers were not aerated and re-suspension of dead organisms was prevented. Experimental sampling was done with a plastic cylinder open on both sides and a rubber stopper. The stopper was gently placed on the bottom and the plastic pipe was vertically lowered onto the stopper closing

Table 1. Experimental design: number of specimens and their body parameters: Total Length (cm), Total Weight (g).

Total Length (cm)	Weight (g)	Container No.
13	50.5	1
19	126.4	2
16.3	80.0	3
21	81	4
17	153	
19.3	147.8	5
16.6	88.5	

sampled water within the pipe. Then the cylinder was picked with its bottom blocked by the stopper. The volume of the sample was measured before filtering through 63 μ mesh size net. All collected organisms were flushed from the net collector into a small beaker and preserved by 0.5 cc (1/10 of the sample volume) of 10% formalin. Counting was carried out under Wild Binocular through wheel-counting-chamber. Each sampling included 3 repetitions and result was averaged. The plankton was divided into the following four categories: 1) Copepod nauplii, 2) 1 - 4 copepodite stages, 3) 5^{th} copepodite stage and adult copepods, and 4) all cladocerans (*Bosmina spp.*, *Diaphanosoma sp.*, *Ceriodaphnia spp*). All concentrations were expressed as number per litre. Number of consumed (eliminated) organisms was considered as those resulting from the subtraction of 2.5 hrs concentration from initial concentration after the elimination of mortality as resulting from concentration measured in fishless containers. In containers with two fishes, results were calculated as number of consumed organisms per individual fish.

2.2. 5 m^3 Outdoor Experiments

The study of the feeding habits of the fish include 4 steps: 1) gut content analysis of lake sampled fishes; 2) Glass containers with individual body size measured specimen (1 - 2 per container) for the investigation of single fish fed by known food items for the study of Index Of Electivity; 3) The 5 m^3 Outdoor tanks contained the background of natural un-treated food resources removed from the lake and the addition of zooplankton, fish and both combination for the preferential habits of the fish. The gut content study was presented earlier and the two steps forward are given here.

Two trials (20, 25 days each) were run in 5 m^3 outdoor tanks filled with lake water to examine the impacts of fish and zooplankton on lake plankton. Tanks were filled at the beginning of each experiment with water pumped from approximately 30 m offshore at a depth of 1.5 m. *T. zillii* were placed into 4 of 8 tanks: 2-with supplemented fresh zooplankton collected in the lake by 300 μ mesh size net and equal portions of the composite added to tanks; 2-control, and 2-with both fish and zooplankton. Treatment combinations were in a 2 × 2 factorial design. Several parameters were measured weekly. Results were analyzed by ANOVA for the significance of main effect and interactions by Duncan grouping for fish and zooplankton treatment. Fish (*T. zillii*) were collected from the lake and acclimated in the tanks filled with lake water several days prior to experimental periods. During experimental time, tanks were mixed for 2 hours a day by an air-lift mixer system. Mixers moved a water volume equivalent to tank volume in about 1 hour destratifying and aerating the tanks. Tanks were weekly sampled for zooplankton counts and Chlorophyll analysis (Wetzel and Likens 2000); by mixing 5 replicate samples collected with 2.5 m-long 1.5 cm-diameter plastic pipe lowered to few cm above tank bottom. Chlorophyll analysis was carried out on pipe samples [17] and zooplankton counts were done using a dissecting microscope on animals collected in a one-net (63 m mesh-size) haul from bottom to tank surface.

3. Results

3.1. Glass Indoor Container Experiment

Results in terms of consumed organisms per fish per 2.5 hrs in 5 containers are given in

Table 2 and Table 3.

The highest number of consumed organisms is due to the smallest-sized Nauplius and the highest consumed biomass to the largest body-sized caladocerans. Nevertheless, the highest index of electivity is that of Nauplius and the lowest that of Cladocerans. The efficiency of small organisms (Nauplius and small copepodites) ingestion (E = 0.73 and 0.22, respectively) is much higher than those of large body organisms (4 - 5 copepodites, adult cyclopoids and cladocerans) (E = −0.04 and −0.11, respectively). *T. zillii* is conclusively considered as filter feeding fish and partly visual attacker.

$$E = r_1 - p_1 / r_1 + p_1 \quad (1)$$

where:

r_1 = % of Consumed Food Component;

p_1 = % of Food Component in the Control at Initial Time.

3.2. 5 m³ Outdoor Experiments

Analyses of three effects were done: Zooplankton Effect, Fish Effect and Main Effect based on data sums across sampling dates in the tanks: 2-control, no fish no

Table 2. Glass Container Experiments: Number of organisms (Nauplius; 1 - 3 stages Copepodite; 5th copepodite and adult copepods; Cladocerans) as concentrations (No./L) decline considered as Glass Container experiments consumed per individual fish.

Container No.	Nauplius	1 - 3 Stage Copepodite	Copepodi 5 + Adult copepods	Cladocerans
1	83	8	14	9
2	121	57	2	24
3	105	18	6	9
4	78	9	3	3
5	39	6	1	9
Averaged Consumed (SD): No./L	85 (31)	20 (21)	5 (5)	11 (8)

Table 3. Consumed Biomass (μg/L) during 2.5 hrs, % are shown. Biomass computation is based on the mean individual wet weight (μg/Individual) in each group [18]: Nauplius-0.9 μg/L; 1 - 3 copepodite stages-4.23 μg/L; 4 - 5 copepodite stages & adults-12.7 μg/L; Cladocera-34.8 μg/L. Biomass (μg/L) and numerical compositions (No./L) of zooplankton in control container at the initial time are given. The outcomes are Indicies of Electivity [19] (see Equation (1)) as shown in Figure 1.

Organism	Biomass Consumed (μg/L)	Biomass Consumed (%)	Control Initial (No./L)	Control Initial (μg/L) (%)
Nauplius	77	13	44	39.6 (2%)
1 - 3 Copepodite	85	14	49	207.3 (9%)
4 - 5 Copepodite & Adults	64	11	20	254 (11%)
Cladocerans	383	62	50	1740 (78%)

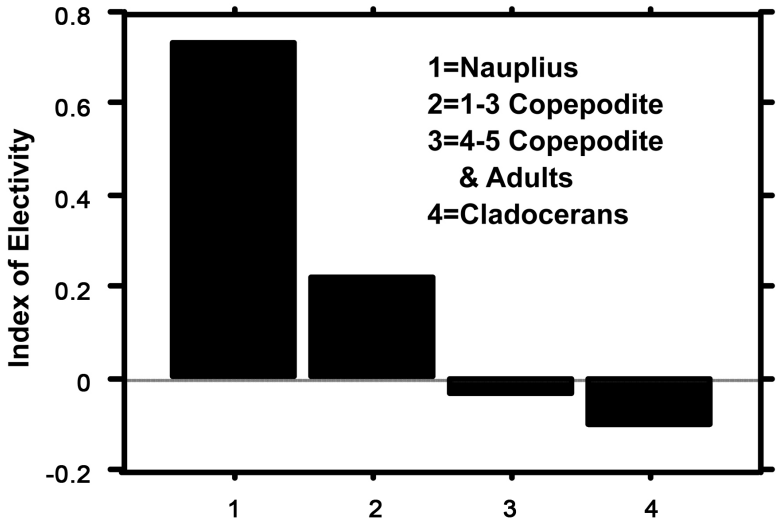

Figure 1. (Glass Containers Experiment): Index of Electivity [19] (See Equation (1)): r_1 = consumed food component biomass (μg/L) and their compositional % averaged for 5 containers; p_1 = Biomas (μg/L) composition (%) in the control container at initial time.

Zooplankton addition; 2-Zooplnkton addition, 2-Fishe addition and 2-addition of Zooplankton and Fish. There was a significant main effect of Fish on Chlorophyll and on Cladoicera in the 1st experiment: $p = 0.048$ and 0.012, respectively; Zooplankton addition significantly affected copepod concentration in the 1st experiment and Cladocera concentration in the 2nd experiment. No significant interaction between zooplankton and fish additions was indicated. In the tanks with fish, chlorophyll increased in the two experiments accompanied by a decline of Cladocera. Evaluation of Fish and Zoopplankton main effects were achieved by comparing the mean values for treatments containing fish and zooplankton with those from which it is absent (Control). Probability values are given in **Table 4** (**Figure 2** & **Figure 3**). Experiments were 2 × 2 factorial design (presence or absence of Zooplankton addition X presence or absence of Fish for the analysis of main and interaction effects. Treatment combination included also nofish-no zooplankton replicate. The community structure information were analyzed using a multivariate profile analysis of repeated measures [20] [21] [22] summary of data across sampling dates into univariate test to detect treatment effects [20].

3.3. Food Composition

3.3.1. Fingerlings

As part of the ecological study of the Kinneret littoral-shallow waters, fingerlings are captured by Electro-Shocker. The sampling program included shallow water (0 - 1.0 m depth) stations along total shoreline length. Among other species, fingerlings of *T. zillii* were fished mostly in the West-Southern and Northern regions. The bottom in those sites was varieties of muddy-sandy-pebble stony compositions. The body size (TL, cm) range of the captured fingerlings was 4 - 8 cm. Samplings were carried out monthly and 5 specimens were sub-sampled. The sub-sampled fingerlings were measured and placed immediately into 10% formalin solution and were later on dissected for the analysis of the gut contents under dissecting and inverted microscopes.

Table 4. Probability values for Zooplankton and Fish main effects and Interactions. Statistical significance (S) was inferred at the $p < 0.1$ level [20] [21] [22] (**Figure 2** & **Figure 3**).

Parameter	Zooplankton Main Effect	Fish Main Effect	Interaction
1st Experiment			
Chlorophyll	0.364	0.406	0.048 S
Copepods	0.021 S	0.462	0.156
Nauplius	0.751	0.590	0.305
Copepodite	0.092 S	0.961	0.294
Cladocera	0.240	0.619	0.012 S
Rotifera	0.310	0.737	0.914
Turbidity	0.874	0.895	0.461
2nd Experiment			
Turbidity	0.463	0.303	1.000
Chlorophyll	0.808	0.704	0.048 S
Nauplius	0.669	0.622	0.114
Copepodite	0.532	0.820	0.760
Cladocera	0.050 S	0.790	0.725
Rotifera	0.976	0.740	0.092 S

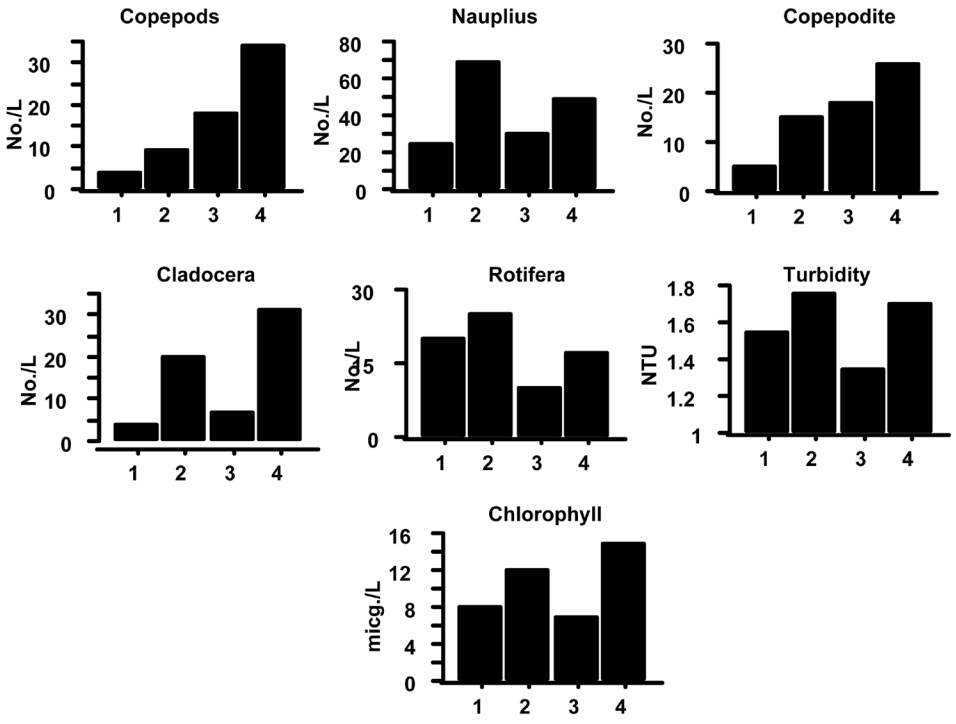

Figure 2. (First Tanks experiment). Mean values in Control (1), Fish (2), Zooplankton (3) and Zooplankton + Fish Treatment (4) combinations: Chlorophyll (μg/L), Turbidity (NTU) and densities (No./L) of Nauplius, Copepodite (1 - 3 stages) Adults and 4 - 5 copepodite stages ("Copepoda"), Cladocera and Rotifera.

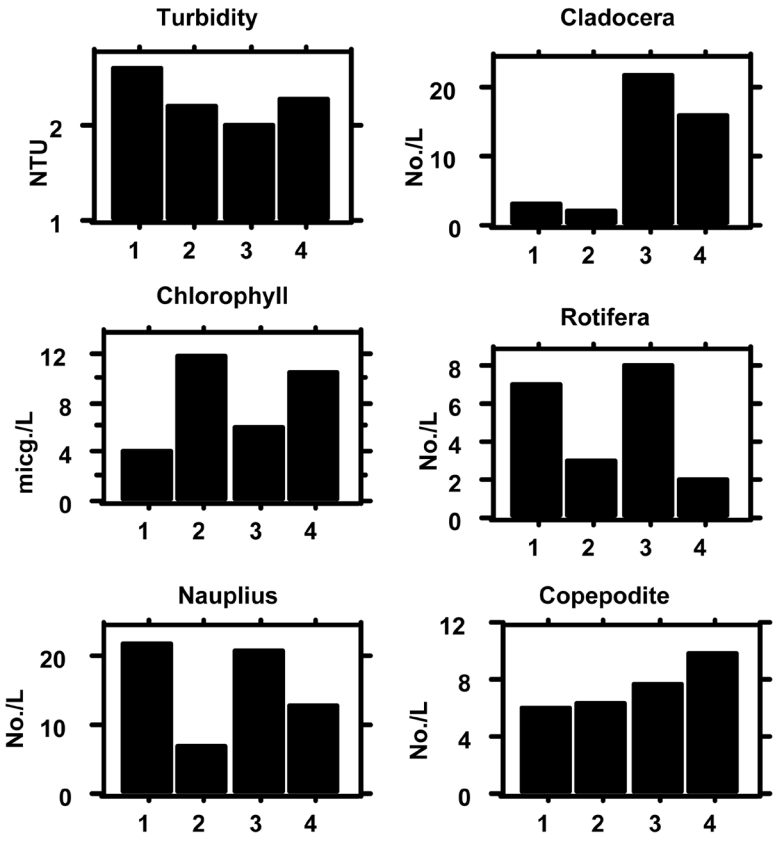

Figure 3. (Second Tanks experiment). Mean values in Control (1), Fish (2), Zooplankton (3), and Zooplankton + Fish Treatment (4) combinations: Chlorophyll (μg/L), Turbidity (NTU), and densities (No./L) of Nauplius, Copepodite (1 - 3 stages), Cladocera and Rotifera.

The most common items in the fingerling intestines were Intact and broken Foraminifer shells, Intact and broken shells of the Gastropod *Melanoides sp.*, sand grains, Frustulae of Centrales and Pennales Diatoms, short (broken) filaments of *Melosira sp.* body parts, (fragments) of *Chironomid larvae*, small size chlorophytes (*Scenedesmus spp.*, *Cosmarium spp.*, *Pediastrum spp.*,), high plant debris, small rotifers (Brachionids), and Spiculae of Porifera. This type of food composition is typical to bottom burrowers or dweller freshwater fishes.

3.3.2. Adults Food

The adults are omnivores which collect food by different techniques [14]: active visual attack, lip palpation of stable items, stone scratching, mud burrowing/dwelling, plankton filtering, and also active prey (young fingerling) chasing. The principal component of the adults throughout most of the seasons is chironomid larvae and zooplankton; supplemental sources are cyanophyte and dinoflagellate algae, periphyton and drifted insects, Nematodes, Ostracodes, Porifera (spiculae).

4. Discussion

The very high range of water salinity (0.4 - 43 ppt Chloride concentration) populated by *T. zillii* is indicates the high saline tolerance of *T. zillii*. Nevertheless, the optimal

condition for a natural complete lifecycle is probably not marine. It is suggested that the origin might be marine conditions but after long-term adaptation the fish's natural habitat was established in freshwater. The high saline tolerance of *T. zillii* is probably an evolutionary relict of marine origin. The food composition of *T. zillii* in marine condition is not known but the documented absence of fingerlings and reproductive behavior confirmed freshwater conditions as preferential habitats. The intensive consumption of the lake and running water food sources indicate an adaptive evolutionary process in freshwater. Moreover, the aggressive reproductive behavior, the diversity of the granulometric composition of the nest structure and substrate composition [4] [5], as well as the versatility of body colored patterns [15], indicate also the high level of evolutionary adaptation of a freshwater fish that originated in a brackish water environment. It can be comparatively considered with the distribution of Mugilid fishes. The mugilids live in marine habitats and reproduce in freshwater river inlets where salinity is lower. Mugilids survive and grow significantly in Lake Kinneret and are cultured in freshwater aquaculture but do not reproduce. *T. zillii* and several mugilid species originated in marine habitats but the former completed evolution and moved into freshwater (Anadromus) when the latter only partly adapted to terrestrial lakes and rivers and live in marine waters.

To indicate the level of freshwater adaptation performed by *T. zillii*, four major features are considered: reproduction, feeding and food relation, tolerance of salinity changes [23] and temperature suitability. The factor of temperature is significant since the fish belong to the Ethiopian region characterized by high temperatures. This factor was discussed in [5] where a case of mass mortality of the fish was documented during exceptional temperature decline in Lake Kinneret followed by a parasite infection [5]. The selected suitability of bottom substrate for nest construction was documented [4]. The wide level of salinity where *T. zillii* was recorded is given in the introduction.

The parameters of feeding and food relations were studied in this paper. It is suggested that adult *T. zillii* preferentially select small zooplankters. Nevertheless, this preferential selection is a result, not of visual collection of food particle, but of swimming and the escapeability trait of the species preyed on. Visible adult cyclopoid copepods and 1 - 4 copepodite stages are better escapers then the non-visible nauplius, young copepodites and small rotifers (Brachionids). Therefore, these small and poorer escaper organisms are consumed through pumping activity of the fish at a higher rate than adults and older copepodites. The ingestion of small organisms (Nauplius, young copepodites and Brachiond rotifers) is maintained by filtration of pumped water, and large animals (matured copepodite, adult cyclopoid copepods and cladocerans) are captured by a visual attack. Significant probabilities were indicated for interaction effect on Chlorophyll enhancement in the two tank experiments, as well as on Cladocera in the first experiment and on Rotifera in the second experiment (**Figure 2** & **Figure 3**). Such chlorophyll enhancement probably resulted from predation pressure of fish produced on small zooplankters (Nauplius and Brachionid rotifers). Nauplius decline (**Figure 2**) is related to fish predation. Interaction effect on Cladocera in the first experiment was probably due to additional zooplankton main effect as fish predation was confirmed by the Index of Electivity (E) (**Figure 1**). Moreover, it is possible that the

poor predation of cladocerans by fish was confounded by zooplankton addition.

The strong adaptation of reproductive behavior, nest construction and taking care of the fertilized eggs and newborn larvae by both male and female are also correlated between the available food sources for the YOY in the shallows of the Kinneret littoral zone. It is suggested that the information collected in the present study and those performed earlier enable lake managers to establish evidence for rules of fishery management legislations aimed at water quality protection and fishery regulations.

5. Summary

The ecological success of the evolutionary adaptation process of *T. zillii* in Lake Kinneret is expressed by the fish's passivity to suitable food required for the adult and the young life cycle stages, a suitable substrate for nest construction and suitable temperatures. This paper documented the food resources suitability for the optimal existence of *T. zillii* in Lake Kinneret. Experiments carried out in glass containers confirmed *T. zillii*'s feeding habits of planktivor filtration and the 5 m^3 tank trials indicated more enhancements of small zooplankters and less cladocerans suppression.

Acknowledgements

I wish to express my thanks to Dr. O. Sonin, Z. Snovski and J. Shapiro for supporting of facilities and assistance of fingerling sampling in the littoral zone (Project No. 596-0527-12). Design, operation and statistical analysis of the Outdoor tank experiments (NSF Research Grant No. BSR-8416519) were carried out by the late Dr. G.L. Vinyard, an outstanding scientist, friend and collaborator.

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