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Study on the Biology of *Tilapia zillii* (Gervais, 1848) in Lake Kinneret (Israel)

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Abstract

Fish (mostly *Tilapia zillii*), (TZ), mass mortality in Lake Kinneret initiated a study of the biology of TZ in Lake Kinneret. The study included several aspects: spawning and nesting behavior, feeding habits, the status of TZ in the Kinneret fishery and temperature tolerance. The merit of TZ to commercial landing fishery is negligible, but this specimen is one of the most common fishes in the lake. Several environmental factors are considered as promoters of the epilimnetic temperature decline: Jordan water inputs in winter season as a heat source parameter. ENSO (EL-NIÑO/Southern Oscillation) acts as a cooling enhancement factor. Supportive data on the impact of ENSO were found in two terrestrial agricultural monitors in the northern and southern parts of the drainage basin. Gut content analysis of young fingerlings and an adult TZ specimen, indicated the significant contribution of benthic sources which are common in the shallows. The great adaptive capabilities of breeding TZ with various bottom habitats are demonstrated.

Keywords

***T. zillii*, Kinneret, Breeding, Temperature, ENSO, River Jordan**

1. Introduction

Tilapia zillii (Gervais, 1848), commonly known as St. Peter Fish, (TZ) is a very common cichlid in Lake Kinneret. The fish is also common in the Jordan River System and throughout the Israeli Coastal Plain rivers. The fish originates from African lakes and rivers [1]-[3]. The salinity tolerance of this fish is very high, and a specimen of it was documented in the Mediterranean [4]. TZ belongs to the Family *Cichlidae*, of which more than 100 genera with more than 1,300 species are known. The native zoogeographical range of distribution cuts across the tropical and subtropical Africa, the Near East, West and East Africa, as well as Israel and Jordan Valley. The body of TZ is yellowish in color with vertical black stripes. The stripe colors of black and silver pattern

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are frequently changed, with respect to the spawning season when the lips turn white. It was suggested that the Kinneret population of TZ should include more than one species or sub-species due to a high variation in body color. Most common total length of adult varies between 12.0 - 22.0 cm (**Plate 1**) [2]. There is a big black spot on the dorsal fin which disappears in big size individuals, and sometimes, the whole body color turns black. The total number of soft rays and spines in the dorsal fin of TZ is 27 or more. In the first gill arch, there are about 8 - 9 gill rakers, unlike other Tilapias, *Sarotherodon galilaeus*, *Oreochromis aureus*, *Tristramella simonis simonis*, and *Astatotilapia flaviijosephi*. TZ is not a mouth breeder; rather, it is a guarding nest spawner. The nest and brood care by TZ are dependent on the nature of the substrate and on the exposure of the nesting location to wave action [5]. Ben-Tuvia [2] documented the spawning season of TZ starting from the month of April to the end of August, with several reproduction cycles in a year. The nests containing the eggs are guarded by both the male and female TZ. The TZ lays and fertilizes a higher number of eggs in comparison with the mouthbreeder Tilapias. The parental nest guarding is more intensive in exposed substrate, or between aquatic plants, where simple nests are constructed on a sandy-clay bottom and abbreviated on excavated deep (20 - 80 cm) brood chambers. The reason for choosing TZ as a typical presenter of the Kinneret Ichthiofauna is due to the existence of its dense population and the wide range of tolerance to environmental conditions. The fish is very common throughout the entire lake in all seasons and known as a nest constructor in the shallows.

2. Nest Structure and Guarding

TZ is a significant obligatory territorial fish breeder. Like other tilapias which originates from Tropical-Ethiopia, its breeding season is in summer. Territorial site selection is initiated by the male, and the female joins later. The bi-parental coupling behavior continue during most part of the year. The nest construction is carried out bi-parentally. Breeding efficiency differs among nest builder fishes under various environmental conditions. These types of environmental alterations frequently occur in shallow lakes, and also, in deep lakes, like in lake Kinneret (44 m and 26 m maximum and mean depths, respectively). High amplitude and frequencies of inundation by the Water Level Fluctuations (WLF) in Lake Kinneret, generate environmental changes in the shallows and in the vegetation beach belt. Consequently, fishes are confined to suboptimal habitats. The bi-parental guarder monogamous TZ covers a wide range of nesting behavior in different exposed of plant, or covered substrates in Lake Kinneret [5]. The common seasonal fluctuations in WL (Water Level) are obviously elevated during winter (January-May), and it declines from mid-May to November, and very minor increase is experienced in December. Nevertheless, due to the national constraint in water pumping from Kinneret, aimed at domestic supply, which generates long term changes and differ in volume with precipitation: decline through sequential droughts and exceptional increase during heavy rainy winter. A decline in WL exposes the beach belt, which is immediately covered by vegetation, mostly *Phragmites australis australis*, and an abrupt increase in WL the subsequent year, create extremities of habitat changes for spawning fishes. The different nesting strategies and structural adaptations of TZ [5] enable it to exploit the Kinneret ecosystem. Two major nest types were found: Shallow "plate saucer" shape, where many guarded eggs are laid and fingerlings are also protected on a sandy-muddy substrate, densely covered by submerged and emerged plants. The female and male TZ guard the eggs together during the incubation period and remove the unfertilized eggs. After incubation, they protect the larvae and young fingerlings. This type of nest is differs from the "shallow saucer" nests of SG by several parameters: SG preferred exposed substrate plants are absent, and the number of eggs laid is much lower and they

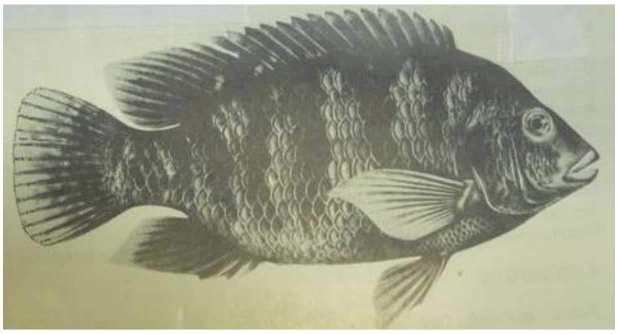

Plate 1. Adult *Tilapia zillii* (TL 20 cm) [2].

are immediately collected by the males and female, rarely "waiting" to be photographed by divers. TZ spawners also maintain courtship and lay eggs on top of uncovered stones/boulders with no indication of nest structure. Wave action disturbance occurs quite often. The granulometric composition of the nest substrate and the space between, was analyzed (for methods see Bruton and Gophen, 1992). The second type of courtship and nest structure is densely distributed, in fully and partly sheltered open lagoons with clay-mud and claying substrate. The nests are found in very shallow and partly sheltered waters and consist of 1 - 3 brood chambers which are 5 cm - 85 cm deep. In fully sheltered lagoons, 1 - 12 brood chambers are located in the middle compound (15 cm - 45 cm in diameter and 2 cm - 25 cm deep), eggs are laid into the chambers and the larvae in there swim outside from time to time. Parental guarding is maintained close to the chambers, accompanied by fins waving for water (and oxygen) exchange. In one site, 957 nests were counted along the 180 m stripe, and along the 85 cm width of a clayed substrate lagoon bank. Shefler [6] carried out fish (commercial size and fingerlings) distribution survey in the Kinneret shallows (0.3 - 1.0 m depth) during the months of May-August. Commercial fish size (net mesh size > 72 cm) of Tilapias (>250 g/ind) included only 5% TZ. TZ is a non-commercial fish in Lake Kinneret due to the small size of its adults (11 - 23 cm TL) and unwanted flavor trait. As part of the British Mandate Authority on Palestine (1918-1948) the administrative responsibility included the formulation of fishery regulation in Lake Kinneret (Lake Tiberias, Sea of Galilee). Dr. C. K. Ricardo Bertram, [7] from the Department of Agriculture and Fisheries, Fisheries Office in Haifa, thoroughly investigated the conditions of fisheries in the lake and submitted a report: Abridged Report on the Fish and Fishery of Lake Tiberias No. 9, 1944. In this report, there are various fishing gears techniques with respect to several fish species, including TZ. On one of the Amendments which is part of Rule 6, it is indicated that the minimum size which may be landed or marketed of TZ (Musht Addadi in the report) is 18 cm TL. Consequently, it can be indicated that TZ was commercially utilized in previous decade. Nevertheless, landings of TZ were completely absent from Lake Kinneret's fishery reports from early 1950's and onwards. Loiselle [8] studied the colonial breeding and territorial behavior of TZ spawning. In his [8] study on site selection, he documented remarkable observations in nest constructing and the share of activity between male and female. The topics discussed are the suitability of nest building site which only referred to the substrate trait and interference by intruders, but parameters like exposure to wave action and sheltered vegetation were not discussed.

3. Granulometric Substrate Composition

The particle size composition of the nest material and the space between nests in the compound was measured in three Kinneret zones: Inlet zone of the Zaki and Masudiya rivers in the nature Reservation area of Beteicha in the East Northern part of the lake; In the Tsalmon inlet zone, on the western middle part of the lake. In this region, a very dense distribution (800 along 1.5 Km) of nests of TZ were documented. The results of granulometric analysis are shown in **Figure 1**. The average of the three locations is shown in **Table 1**.

The results in the **Table 1**, **Table 2** and in **Figure 1** clearly indicates that TZ fishes selected a larger particle size substrate for nest construction within the sheltered region. Cummings [9] indicated that no nests in the open shore sites were free of merged vegetation (reeds). Low densities of vegetation covered zones were preferred by

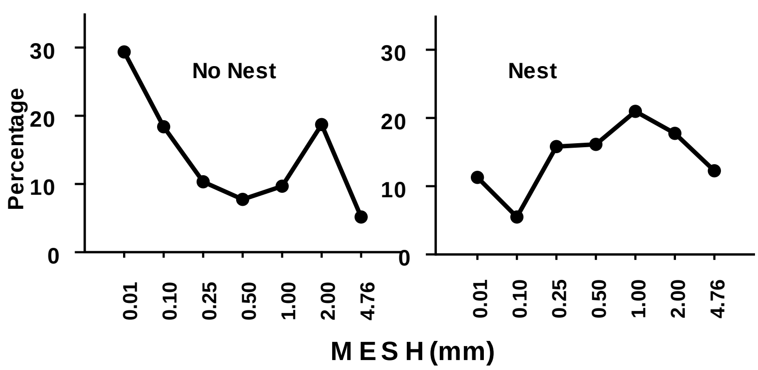

Figure 1. Dry weight (g) of mesh fraction (see text): Y axis = DW%; X axis = mesh fractions (mm); nest = nest substance; no nest = space between nests.

Table 1. Averaged percentages (dry weight) of coarse (4.76 mm - 1.00 mm mesh) and fine (0.50 mm - 0.01 mm mesh) particles.

Particle size fraction	No nest space	Nest
Coarse: 4.76 - 1.0 mm	34	51
Fine: 0.5 - 0.01 mm	66	49

Table 2. Mean dry weight (g) of each fractions (coarse and fine) locations of inlet rivers, Kursi and Zaki.

Location	No nest space	Nest
Zaki	17.2	62.2
Kursi	24.4	57.7

Tilapias as their breeding substrate [9]. Nevertheless, in several beach segments throughout the entire lake, the shoreline nests of TZ were absent. It is in partial contradiction with [5], which reported about the TZ breeding activity in those beach segments. Bruton and Gophen [5] concluded that 4 critical substrate parameters control the suitability of TZ breeding: exposure to wave action, granulometric composition, water depth and macrophyte density. Each one of those factors, and any combination of all, might be the limiting factor. A prominent photo presentation of TZ nest with eggs ([5]; **Figure 2**, **Figure 3**) is shown in [9]. Cummings [9] indicated maximal breeding activities of *S. galilaeus* and *O. aureus* from mid-April to mid-June and that of TZ, later, ((June-September). Moreover, presented photos [9] confirm bottom habitat selection of un-covered sites by submerged vegetation.

4. Temperature Tolerance and External Parasite Infection

4.1. Fish Mortality

In February 1973, a massive fish kill was observed in Lake Kinneret. The signal was initiated by a dense population of the winter migratory bird Seagull (*Larus ridibundus*), mostly found in shallow water sites along the lake shoreline. Dead fishes were collected and all of them were identified as TZ. Observations along the entire Kinneret shoreline were accompanied by water sampling and the fishes were given to experts in fish diseases for potential fish mortality factors. The sampled fishes were at all levels of infection development from moribund to mortality. Many of the infected fishes were partly covered by the fungus *Saprolegnia* sp. and they moved very slowly. Infected fishes hosted the external parasite, *Childonella* sp. on the skin, gills, scales and fins. It is a well known phenomena in Tilapias, that low temperatures induce a reduction in the tolerance level of the fish to parasites intruders. We observed that several cases of Tilapias mass mortality is as a result of sharp decline in temperatures, especially in the shallows. Internal damage caused to the infected TZ were also documented: enlarged gall bladder full with transparent liquid, enlarged pale liver and no food particles in the intestine that contained transparent liquids. Other healthy Tilapias which had been raised with infected TZ had died within 3 - 5 days. Plate culture of blood samples has indicated the presence of *Aeromonas liquefaciens*. Each one of the three factors might be the sole or combined reason for the massive kill: the bacteria *A. liyuefacience*, the protozoon Childonella and the fungus Saprolegnia. The bacteria is widely known from aquaculture as being more violent when the fish is under stress and at low temperature is known as a stressor.

4.2. Water Level Fluctuations

TZ is mostly concentrated in shallow waters, where the amplitude of temperature fluctuations is high. It was concluded that the primary stressor was at low temperature which induced and enhanced the Bacterial and Protozooan infection. Lake Kinneret Data analysis (simple regression) indicated significant relationship ($r^2 = 0.057$; $p = 0.0049$) between the water level monthly change in winter months (1 - 4) and the temperature of the Epilimnion. Thus, it is possible to inquire about the relationship between long term record of the Kinneret epilimnion and the temperatures in the shallow waters. Supportive information originate from the existing information on the epilimnion temperatures and the water level fluctuations. The outcome merit is the temperatures on the shallow waters of Kinneret. **Figure 4** shows an exceptional decline in the epilimnetic temperatures during the year 1973, when the massive fish kill occurred. Moreover, data shown in **Figure 5** indicates the direct significant

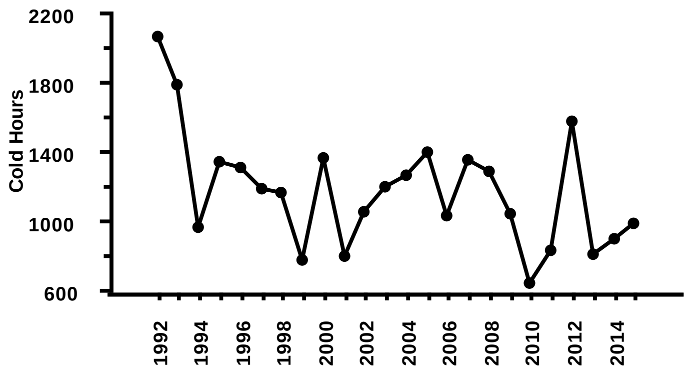

Figure 2. Total number of "Cold Hours" (see text) in the Mid-Hula Valley Station ("Matityahu Ranch").

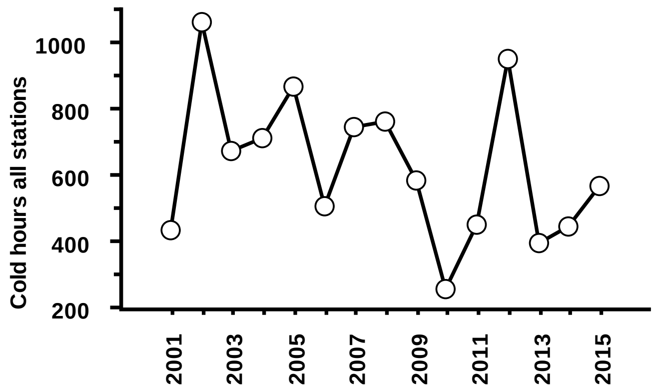

Figure 3. Total number of "Cold Hour" in the Southern part of the drainage Basin and in Lake Vicinity Stations.

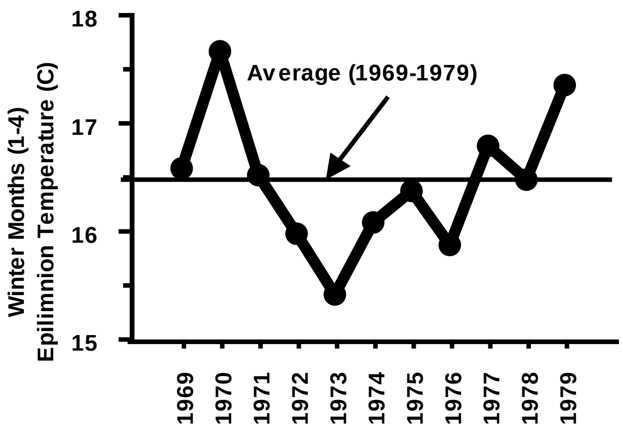

Figure 4. Seasonal (winter months: 1 - 4) Averages of epilimnetic temperature (˚C) in Lake Kinneret during 1969-1979.

($r^2 = 0.034$; $p = 0.04327$) relationship between the averaged (1969-2003) monthly temperatures and water level. Conclusively, the combination of low altitude and sharp decline in seasonal WL induce temperature decrease in the shallows. In the year 1973, the winter average of the WL was lower by 1.25 m than in the previous year, causing a "cold strike" in the shallows. During 1974-1976, the WL altitude was low, but without a seasonal sharp fluctuation. Similar situation occurred also in 1990, when the decline was 1.6 m lower than in 1989, which induced a "cold strike" and massive fish kill of Tilapias (*S. galilaeus*, *O. aureus*, *T. simonis simonis*, and

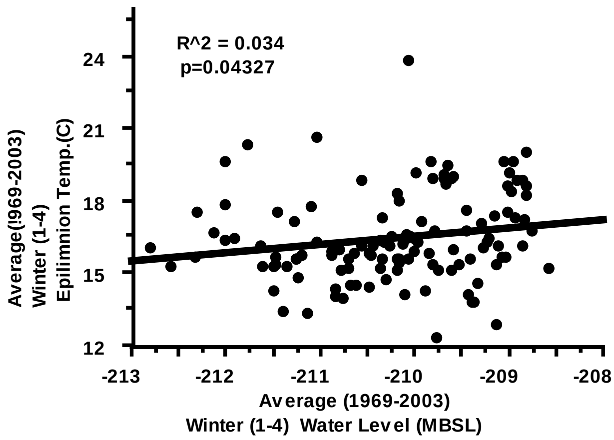

Figure 5. Simple regression (r^2 and p values are given) between Averaged (1969-2003) epilimnetic temperature (˚C) vs. winter monthly (1 - 4) means of WL.

T. zillii). Conclusively, the low temperature affecting Tilapias in Lake Kinneret is not because the WL altitude is low, but its probably due to the combined impact of low temperature and sharp WL decline. The Jordan waters input into Lake Kinneret during the winter season (January-April) is not only an influx of water and nutrients, but also due to heat contribution. That is because during winter, the temperature of the Jordan waters is higher than that of the Lake Epilimnion [10] [11]. Consequently, the higher and longer the Jordan discharge, the greater the contribution of heat to the epilimnion. The consequence of smaller WL elevation in winter is a lesser epilimnetic heat capacity, which enhance the weakening of tropical fish tolerance and pathological damages (see **Figure 6**). The significance of drought has a long term seasonal (winter) effect of lesser water and heat inputs and therefore, fish "cold strike". It is not a short term (hours, days) effect, but involves a longer time (weeks). Besides the direct influence of air temperature (climatology) on the temperature of the epilimnion, a significant and secondary parameter is heat transfer by the Jordan waters. The climate issue is not discussed here, but only the impact of the Jordan waters is. When precipitation decline (drought), Jordan discharge reduce, WL in the lake decrease, and the input of heat through Jordan inflow is lowered, the epilimnetic temperature consequently decline. The decline in sharpness and longevity enhance "cold strike" and Tilapias infections. [12] documented TZ mortality as a result of temperature decline below 11.2˚C with maximal limit of 6.5˚C. The author [12] described TZ survivorship of 2 weeks in nature, if exposed to a continued temperature of 13.0˚C in nature. Lenger Medved [15] indicated a minimum temperature tolerance of TZ as 7˚C, whilst [13] reported 9˚C as the minimal tolerance. Under temperature decline, TZ declined in feeding rate, lethargic, lost equilibrium and died. The impact relations are probably summarized as follows: The temperature of the Jordan water in winter are higher than those that existed in the lake epilimnion, therefore, the Jordan input is not only water and consequently WL elevation, nutrients, and suspended matters, but also heat. Consequently, higher input is an epilimnetic heating factor and lower inputs might be followed by cooling, with enhancement of fish disease and parasite infections in sensitive Tilapias.

4.3. Temperature Impact on Growth Rate

EL-BOLOck and KOURA [14] documented information on the age and growth relations of TZ in the Beteicha lagoons (North-Eastern Kinneret region). The area of this inundated region vary between 5 - 20 ha, with maximal water depth of 2 m - 3 m in summer and winter, respectively. These conditions were similar to those that existed 30 years later during [5] research (1992). Nevertheless, in the 1961 report, the majority of the stock is due to *Sarotherodon galilaeus*, and the minority to TZ. [14] analyzed the Weight/Length relationship and condition factor calculated: K = Condition factor = W × 100 (g)/L (cm); 176 specimen were measured, ranges of Length and Weight were 9.0 - 21.0 (cm) and 16.0 - 165.8 (g), respectively. The K values were higher for smaller individuals and the total mean was 1.84. Similar to the pathological information given in this paper, during late 1950's, 60% (mostly large individuals, >15 cm TL) of all TZ sampled in Beteicha were infected by the external-parasite worm [14]. The parasite symptomatic view was a 3 mm yellow spot beneath the scales and it is

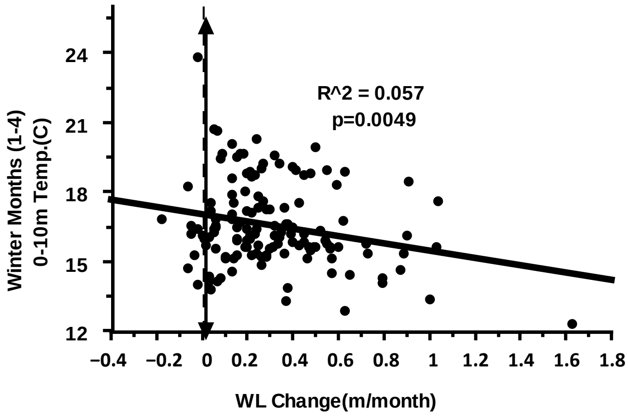

Figure 6. Simple regression (r^2 and p values are given) of Winter month (1 - 4) averaged epilimnetic temp (˚C) vs. WL monthly changes (m/month).

scattered all over the body. The condition factor of TZ was low-1.84, in comparison with 2.20 and 1.98 for *S. galilaeus* and *T. nilotica*, respectively. *S. galilaeus* was not infected at all and very few individuals of *T. nilotica* were damaged. These data confirm the previous conclusion about the low temperature tolerance accompanied by intensive pathological attack of TZ. They [14] also concluded That TZ growth rate is slower than that of the other two Tilapias, probably as a result of Temperature sensitivity [13] [15].

4.4. ENOS (EL-NIÑO/Southern Oscillation) Contribution

The potential effect of ENSO on the Tilapias assemblages in Lake Kinneret was previously suggested (Gophen, 2015; 2016). The outcome of the impact of ENSO events on the local climate is expressed by longer and cooler winters, which might enhance damages to Tilapias. Previously [16] [17], it was studied by indicating simultaneous climatological and fishery parameters. As a complementary investigation, I incorporated field information collected in the Hula Valley and Jordan Valley located in the vicinity, to the southern side of Lake Kinneret. Continuous (every 10 s) monitoring of temperatures taken at 2 m above the ground in a meteorological station (Namely "Matityahu Ranch") located in the middle of the Hula Valley north to Kinneret. It is a part of the services given to farmers in the region [18]. The data was evaluated to hourly mean values and indexed as follows: an hourly mean temperature of <7˚C was indexed as 1; an hourly mean temperature range between 7˚C - 10˚C was indexed as 0.5; an hourly mean temperature range between 10˚C - 18˚C was indexed as 0. All values above 18˚C were ignored. Indicies were accumulated to monthly values entitled "Cold Hours" (**Figure 2**, **Figure 3**). The data record duration of "Matityahu Ranch" lasted 24 years (1992-2015) (**Figure 2**). Additionally, shorter records (2001-2015) from stations in the vicinity of the lake were also considered (**Figure 3**). Results in **Figure 2**, and **Figure 3** indicate a corresponding relationship between the ENSO event and a high number of "Cold Hours". The multi annual (1992-2016) average of "Cold Hours" number in the Hula Valley ("Matityahu Ranch") was 1174.2. Thirteen years values were above the average, of which 9 (70%) of them corresponded with the ENSO events. In the other stations (**Figure 3**), the mean value was 176 "Cold Hours" with high values in 2003 and 2004, which also correspond to the ENSO events [16]. A different support came from another data record which differ from the "Cold Hours" model by several parameters: location, duration and method. The record is based on daily measurement (2 m above the ground and an exposed thermometer at land level) of minimal temperature impact. A measured values of <2.5˚C and 0˚C at ground level, were classified as "Frost" [19]. The data record continued for 54 years (1961-2015). Out of the 55 years, 13 were classified as years of "Frost", of which 7 (54%) corresponded with the ENSO events (**Table 3**). Conclusively, it is suggested that ENSO event might have an impact on the biology of Lake Kinneret's Tilapias. This potential effect is probably related to Tilapias sensitivity to diseases or parasite infections.

5. Food and Feeding Habits of TZ Gut Content Analysis

The omnivorous trait of the adult food composition which include planktonic and benthic components, together

Table 3. Frost and strong frost years as recorded by [19] and corresponded ENSO event [16]. The "+" symbol indicates occurrence.

Year with frost	Strong frost	ESNO event
1964		+
1972	+	
1973		
1982	+	+
1989	+	
1992		+
1993		+
2004	+	+
2005		+
2008		
2010	+	+
2014		
2015		

with high plants debris was documented in [2]. Spataru [20] reported that the ability of TZ to collect zooplankton organisms is low. Zooplankters presented in the gut of adults were probably collected from zooplankton swarms or at high densities in the shallows. Spataru [20] also reported some benthic organisms like Nematods, Ostracods, spicula of Porifera, and even preyed small fingerlings. It was noted that TZ is known as an agressive animal which intensively attack other TZ individuals. In recent studies, the food composition of young TZ was analyzed. The gut content of adult TZ (TL > 10 cm, W = 120 g) in December 2014, was dominated by small foraminifers and sand grains, indicating materials collected from the bottom. The gut content of fingerlings of TZ (TL = 3 - 4 cm) in July 2015, was dominated by fragments and entire conch of *Melanoides* sp. The source of bottom burrowing substances is indicated. El-Bolock and Koura [14] suggested that there is plenty of plankton suitable food for *S. galilaeus* and *T. nilotica*. Data given here indicates TZ preferential feeding of benthic organisms. It is assumed that the difference in feeding habits and food composition is partially responsible for the low rate of growth of TZ, in comparison with *S. galilaeus* and *T. nilotica*.

6. Summary and Conclusion

The biology of *Tilapia zillii* in Lake Kinneret was evaluated. The food resources for adults and young fingerlings are located at the bottom of the shallow waters. The nest construction is carried out by the male and female, and coarse grain matters in habitats shallower than 2 m, are preferably selected. Nests are constructed in sheltered and in exposed substrate to wave action. Massive fish kill, mostly *Tilapia zillii*, was the result of extreme temperature decline. Record of water level, epilimnetic temperature and Jordan discharges indicated the impact of heat input in winter through the Jordan discharge. Two independent methods of temperature monitoring in terrestrial habitats accompanied by the winter temperature of the Kinneret Epilimnion partly confirmed the influence of ENSO cases on the epilimnetic heat decline accompanied by increase in fish availability to disease and parasite infection.

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