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Ecological Dynamics in the Kinneret Littoral Ecosystem

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Abstract

A study of the Kinneret Littoral ecosystem is presented. Environmental parameters were integrated, aimed at evaluation of the Littoral ecosystem functioning: Water Level Fluctuations Index (WLFI), commercial fish landings with respect to stock assessment, fingerling food sources and density distribution, the beach vegetation impact, spawning intensity of nest builder-mouth breeder tilapias. It is concluded that WLFI is not affecting reproduction whilst long-term low WL altitude reduces the intensity of nesting by *Sarotherodon galilaeus* and *Tristramella simonis simonis.* Low WL did not affect reproduction of *Coptodon zillii* (*Syn. Tilapia zillii*). Density of fingerlings was not correlated with Inundated Beach vegetation during WL decline. Nevertheless, submerged macrophytes and shadowing Tamarix trees were preferably utilized by fingerling shoals as documented in the north-eastern half open lagoons of the lake shallows (Beteicha).

Keywords

Kinneret, Littoral, Tilapias, Water Level, Vegetation

1. Introduction

The management design of Lake Kinneret encountered presently a decision-making dilemma of whether lake utilization for human welfare is possible without compromising on ecosystem structure and function. In other words, whether ecosystem services should be ignored just for the lake ecosystem protection, ignoring human benefits. Lake Kinneret managers are presently confronting a complicated situation comprised of controversial factors of ecology which is the expansion of inundated nearby vegetation associated with lake water level decline. Vegetation removal could have implications for the recruitment of mouth-breeder-nest-constructor Tilapias: *Sarotherodon galilaeus, Oreochromis aureus*, *Coptodon* (*Tilapia*) *zillii* [1] and *Tristramella simonis simonis. S. galilaeus, O. aureus* and *T. simonis-simonis* construct their nests on sandy-silty-clay muddy surface-plant free substrate at 0.5 - 3.0 m depth of water; *C. zillii*, construct different type and size nests from shallow wide depression beneath aquatic plants and on pebbles, to deep (80 cm) vertical tunnel in muddy plant free bottom substrate. Further onwards independent shoals of fingerlings (YOY) selectively prefer the habitat space of inundated submerged macrophytes and/or partly water covered terrestrial vegetation (*Phragmites* sp., *Tamarix* sp., *Potamogeton* spp. *Myriophyllum* sp. *Ceratophyllum* sp. *Najas* spp.). When submerged vegetation is not available, fingerlings also assemble within stony habitat where stone of different sizes cover the bottom substrate.

During the last 20 years, the Kinneret ecosystem structure has undergone significant modifications. The algal dominance of the bloom forming *Peridinium* was replaced by Cyanobacteria, and the fish pelagic food resources were modified by intensification of zooplankton suppression. The landings of *S. galilaeus* were temporally declined but increased after 4 years of slump. Several factors were defined as causation of the decline: fishery pressure enhancement, increase in the population size of the fish predator, the Great Cormorant (*Phalacrocorax carbo*), a reduction in the stock of *S. galilaeus* fingerlings, enhancement in the use of illegal small mesh size of fishing nets, elimination of Bleaks fishing and its stock proliferation followed by a sharp decline of marketing , the outburst of a viral disease (TilV-RNA-NODA-the blindness disease), which infected mostly *Sarotherodon galilaeus* and *Tristramella simonis simonis.* The Natural cyclic fluctuations of the *S. galilaeus* stock also contributed to the population decline. An essential migration of the fish shoals to find refuge (Cormorant protected) in deeper layers, making its detection and capture more difficult, was also a merit for the landings decline.

The optimization of the fishery management crucially includes a comprehensive involvement of a wide range of ecosystem's structural parameters where fishermen's income, nature conservation, and water quality protection, including water level fluctuations (WLF), are integrated. The objective of this paper is an insight into a solid scientific information and into what is presently accounted as the virtual concept of "Prevention by Carefulness" (have been defined by UNESCO in 2005 as: "The Precautionary Principle") as crucial service for decision making regarding the littoral management program aimed at both human welfare, lake water quality and nature preservation.

The food components of fish larvae when compared to their counterpart, adult stages, are essentially different within the food-web structure [2] [3] [4]. Planktivory is a dominant feeding trait among the Kinneret fishes whilst fingerlings feed on bottom resources. There are two distinctly different larval development periods [1] [2]: larval dependence on internal metabolic supply from the yolk sack transitioned to exogenous utilization of food resources than followed by metamorphic changes towards becoming a juvenile or fingerlings. The present study deals with fingerling stages after metamorphosis when the organism is fully independent and carrying on all body functions as an adult, except reproduction. Most of the fingerling food items documented in this study are non-moveable or maintain partial mobility, not planktonic, such as small Gastropods, Oligochaeta (Tubificide), Chironomid larvae and Eggs, Epiphytic Chlorophytes, Spiculae of Sessile Sponge (Porifera). Residuals of zooplankters were probably unintentionally ingested or captured by burrowing underneath stones. (*Harpacticoida, Onychocamptus mohammed*). It was earlier documented [2] that zooplankton (instars and adults) is the main source of fish larvae where the prime food are cladocerans. Earlier studies also documented zooplankton as main food for larvae of Kinneret fishes [3]-[8].

2. Material and Methods

Water Level Fluctuations (WLF) (**Figure 1**).

In order to find a potential relation between WLF, cover intensity of beach vegetation, bottom substrate feature and fingerling food composition, the data on WLF was evaluated. The merit of aquatic plant bottom cover to fingerling survival was also considered because of substrate availability for nest construction and fry refuge. The WLF data (1936-2016) was taken from the [9].

The littoral zone is determined in this paper as the shallow water zone limited between depth bordered between 0 to 1.5 meters. In multiannual considerations this shallow belt is changed according to *WLF*. The index of Water Level Fluctuation was calculated by averaging monthly changes of the water level *i.e.* Periodical (annual groups) Sum of ($WL_0 - WL_i$) monthly values in m divided by 100 to get it in cm units throughout the total year group period.

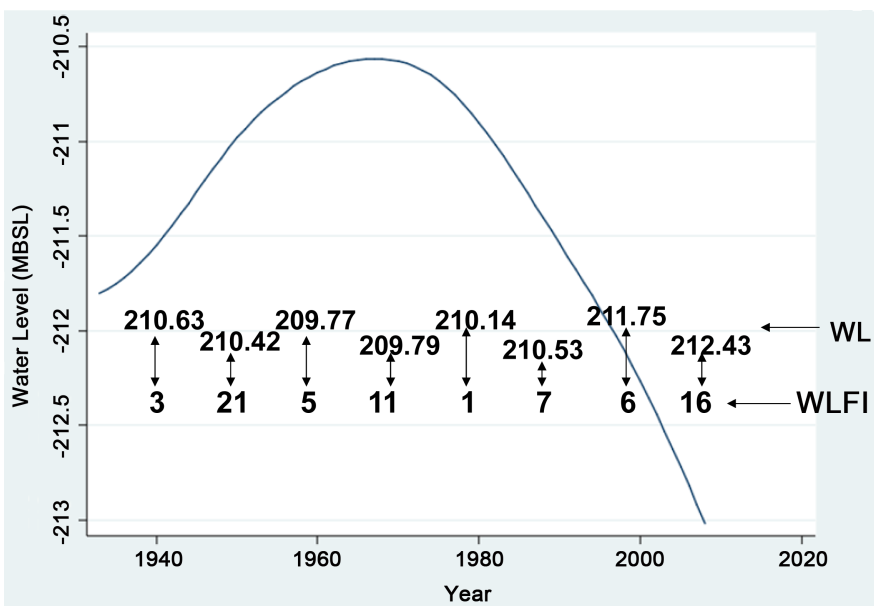

Figure 1. Fractional Polynomial of monthly means of Water Level in Lake Kinneret during 1936-2016. Row of numbers are Decade (**Table 1**) averaged WL (upper) WLFI (lower) (see text).

WL_0 = Monthly mean of initial WL.

WL_t = Monthly mean WL one month later than WL_0.

WLFI = The total summary of ($WL_0 - WL_t$).

Example: If ($WL_0 - WL_t$) = 0.3 (increased WL) and the consecutive value is −0.3 (WL decline) the index is 0.

2.1. Beach Vegetation Mapping [10]

A set of Air Photos of the Kinneret Beach vegetation in the vicinity to the entire shoreline was carried out in 5.5.2012 when WL was high (Figure 1) by A. Dori, National Authority of Nature Conservation and National Parks, and decoded and published by Kinneret Limnological Laboratory. Total number of photos were 600, more than 10 per 1 km of beach. Three levels of vegetation density were indicated: 1) Dense-45% of shoreline total length; 2) Dispersed-16% of total shoreline length; 3) No vegetation-39% of total shoreline length. The level of vegetation cover was encoded by topographic visualization of combined air photos indicating density level as dullness performance in the photos.

2.2. Statistical Methods

Statistical analyses used in this study were taken from STATA 9.1, Statistics-Data Analysis and StatView 5.1, SAS Institute Inc. The analyses used were: ANOVA ($p < 0.05$), Polynomial and Linear Regressions, Fractorial Polynomial Prediction, LOWESS (0.8).

2.3. Water Level Record

Monthly averages of the Kinneret Water level was taken from the Lake Kinneret Data Base-Tahal and Water Authority (1936-2016). The long monitored period of 80 years, started after the construction of the south Dam (1936), until 2016, was grouped into 8 periods of 10 years each (Table 1).

Figure 1 represents annual means of WL in Lake Kinneret during 1970-2015 and two levels are lined: 1) 212 MBSL indicating common altitude prior to the operation of the National Water Carrier (1964); and 2) 213 MBSL which is the present legislated lowest permitted WL altitude whilst actually lower than that was quite often managed.

Table 1. Periodical decades used in this paper.

Decade Number	Years
1	1936-1945
2	1946-1955
3	1956-1965
4	1966-1975
5	1976-1985
6	1986-1995
7	1996-2005
8	2006-2016

2.4. Fingerling Sampling

Fingerlings were sampled monthly by Electro-Shocker at 0.0 - 1.0 m depths at 10 stations along the entire lake shoreline. The bottom substrates in the sampling sites were varieties of muddy-sandy-pebble and stony compositions. Fingerlings were captured, identified, counted and body length was monitored. Five specimens of each sampled species were sub-sampled, preserved immediately in 10% formalin solution and later dissected for the analysis of the gut contents under dissecting and inverted light microscopes.

2.5. Fingerling Food Composition

Earlier studies about the feeding habits of Bleak (*Acanthobrama terraesanctae terraesanctae* and *Mirogrex lissneri*) fingerlings [6] [8] [11] indicated free swimming zooplankter as the major food component. The fingerlings of the following species are presented in this study: *Astatotilapia flavijosephi, Salaria fluviatilis*, *Barbus canis, Clarias gariepinus, Garra rufa, Hemigrammocapoeta nana, Tristramella simonis simonis, and Neomachilus leantinae.*

2.6. Commercial Fisheries

Data on Commercial Fisheries in Lake Kinneret is routinely published (Fisheries Department 1950-2017) and results given in special report (2000-2015) [12] were accounted here. The data selected for the present study refer to the two relevant native nest-builder-mouth-breeder tilapia species: *Tristramella simonis simonis* and *Sarotherodon galilaeus* and the most abundant species, the endemic Bleaks (*Acanthobrama terraesanctae terraesanctae* and *Mirogrex lissneri*) [13].

3. Results

3.1. Water Level Fluctuation Index (WLFI)

Results given in **Figure 1** (average WL per decade) indicate Water Level (WL) elevation from the 1st (−210.6 MBSL) to the 4th decade (−209.8 MBSL), and from the 5th through the 8th decade a decline of WL by 2.6m.

The monthly changes of WL were calculated by subtraction of each monthly mean WL from previous monthly mean value. During the winter months it was obviously mostly positive value (*i.e.* an increase) whilst during the summer periods it was negative, *i.e.* a decline. In order to evaluate one mean value of monthly changes per decade, the following evaluation was carried out: all values of a decade were arithmetically averaged. This final value of only fluctuation measures might be negative (if negatives > positives) or positive (if negatives < positives) but have no influence on the absolute altitude of the WL periodical change. This value is termed as "Water Level Fluctuation Index" (WLFI), which is a measure indicating the amplitude range of fluctuation. High WLFI I (positive or negative) mean high amplitude of fluctuation and vice versa. The results are given in **Table 2**.

Table 2. Water Level Fluctuation Index (WLFI) (cm) per Decade (see Table 1).

Decade	Periodical WLFI (cm)	Counts
1936-1945	3	118
1946-1955	21	110
1956-1965	5	120
1966-1975	11	120
1976-1985	1	120
1986-1995	7	120
1996-2005	6	120
2006-2016	16	131

Results in Table 2 emphasize three periods of high WLFI values caused by exceptional WL fluctuations: During the 1946-1955 high amplitudes of increasing WL management, the higher WLFI values were caused by a succession of droughts and heavy floods events (Figure 1).

3.2. Gut Content Composition

The numerical composition of gut contents as averaged for 5 specimen of each species per sampling station is given in Tables 3-10. The body size of the fingerlings is given. Composition was classified in three levels of frequency: 1) Abundant (above 50% of observed items); 2) Medium (between 10% - 50% of observed items); 3) rare (less than 10% of observed items). Sampling stations (numbered with local name) were as follows.

A: Western side of the lake: No.1:Biriniki; No.2: Migdal; No.3: Ginosar; No. 4: Ohalo; No.5: Lido. No.6: Ginosar-Arbel;

B: Northern part: No.7: Amnon Bay;

C: Southern part: No.8: Maagan;

C: Eastern part: No.9 Ein-Gev ; No.10 Ein-Gev South.

The food composition of fingerlings of *Coptodon (Tilapia) zillii* was given in [14].

Results in Table 3 indicate food collections by a bottom shallow dwelling. The fingerlings of *A. flavijosephi* are not a filter feeder.

Results given in Table 4 indicate the feeding habits of *Barbus canis* as stone scraping or delving into sandy substrate.

Results given in Table 5 indicate that *Clarias gariepinus* is an omnivore feeder fish (Spataru *et al.*, 1992) which feeds on items that are most available such as bottom items (human wasted corn grains), plant debris or fingerling prey. It is suggested that food is collected close to the bottom. Lack of food in winter is evidenced by empty intestines.

Garra rufa preferably populates the Kinneret littoral environment where food is collected from sandy or muddy bottom resources. Due to the high density of *G. rufa* within the littoral ecosystem, its organic matter recycling capabilities are beneficial.

Table 3. Species: *Astatotilapia flavijosephi* Body size (TL cm): 3.0 - 5.0.Sampling Time: December-January.

Component/Station No.	Abundance Level (see text: 1,2,3)
Station No. 1	
Detritus	1
Microcystis Colonies	1
Tubificid	2
Chironomid eggs	1
Chironomid Larvae	1
Fish Scales	2
Station No. 10	
Chironomid Larvae	1
Sand Grains	1
Bazalt Grains	1

Table 4. Species: *Barbus canis*; Body size (TL cm): 8.0 - 10.0. Sampling Time: June-August.

Component/Station No.	Abundance Level (see text: 1,2,3)
Station No. 7	
Detritus	1
Microcystis Colonies	1
Plant Debris	1
Epiphytic Chlorophytes	2
Oscilatoria	2
Station No. 2	
Onychocamptus	1
Plant Debris	2
Amorphic Silty Particles	1

Table 5. Species: *Clarias gariepinus*; Body size (TL cm): 23.0 - 70.0. Sampling Time: January-June-August.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No. 9	
Prey:small Aphanius, and Salaria	3
Corn seeds	2
Bazaltic grains	1
Station No.9: Intestine empty	
Station No. 3:	
Potamon potamios (fragments)	2
Terrestrial Insects: Coleoptera, Ants, Vespidae	1
Calanoids fragments	1
Brachionids	1

Continued

Plant Debris	1
Detritus	1
Small Ostracods	1
Daphnia	3
Station No. 4	
Amorphic silt particles	1
Copepods Fecal Pellets	1
Cyclopoid Fragments	2
Sand Grains	1
Prey: Small Salaria	3
Tintinids	1
Terrestrial Insect Fragments	2
Plant Debris	1
Chironomid Larvae	1
Filinia	3
Diatoms, Penales	2
Nemaods	2

Table 6. Species: *Garra rufa*; Body size (TL cm): 6.0 - 4.0. Sampling Time: June-September.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No. 3	
Diatoms, Penales	1
Sand Grains	1
Foraminifers	1
Zooplankton Fragments	3
Plant Debris	2
Spicilae (Porifera)	1
Station No. 7	
Diatoms, Penales	1
Brachionids, Synchaeta	2
Plant Debris	1
Station No.5	
Diatoms, Penals	1
Spiculae (Porifera)	3
Bazalt grains	1
Sand Grains	1
Plant Debris	2
Station No.3	
Diatoms, Penales	1
Spiculae (Porifera)	1
Sand Grains	1
Foraminifera	1
Zooplankton fragments	3
Plant Debris	2

Table 7. Species: *Hemigrammocapoeta nana*; Body size (TL cm): 8.0 - 4.0. Sampling Time: August.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No.6	
Diatoms, Penales	1
Spiculae (Porifera)	1
Sand Grains	1
Station No. 7	
Diatoms, Penales	1
Ostracode Shells	1
Plant Debris	2
Chlorophytes	2
Brachionids	2
Butterfly Scales	3
Chironomid eggs	2

Table 8. Species: *Salaria fluviatilis*; Body size (TL cm): 7.0 - 3.0. Sampling Time: February-September-December-June.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No. 5	
Tubificids	2
Plant Debris	1
Filamets Cyanophyta	2
Diatoms Penales,	1
Fragilaria, fragments	3
Spiculae, (Porifera)	3
Station No. 7	
Aulacoseira granulate	1
Butterfly scales	3
Sand Grains	1
Plant Debris	1
Zooplankton Fragments	2
Station No. 1	
Chironomid larvae	1
Butterfly scales	3
Sand Grains	1
Detritus	1
Onychocamptus mohammed	1
Station No. 10	
Chironomid larvae	1
Sand Grains	1
Bazalt Grains	1

Table 9. Species: *Tristramella simonis simonis*; Body size (TL cm): 8.0 - 3.0. Sampling Time: June-August.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No. 5	
Spiculae (Porifera)	3
Plant Debris	2
Sand Grains	2
Bazalt Grains	2
Station No. 3	
Diatoms, Penales	1
Filaments Cyanophytes	1
Staurastrum	1
Spiculae (Porifera)	2
Sand Grains	2
Chydorus sphaericus	3

Table 10. Species: *Neomachilus leantinae;* Body size (TL cm): 10.0 - 7.0. Sampling Time: June-July.

Component/Station No.	Abundance Level (see text: 1-2-3)
Station No. 2	
Plant Debris	1
Detritus	1

Results given in **Table 7** indicate the feeding habits of *Hemigrammocapoeta nana* as stone scraping or delving into sandy substrate.

Salaria fluviatilis preferably populates the Kinneret littoral environment where food is collected from sandy or muddy bottom resources. Due to the high density of *Salaria fluviatilis* within the littoral ecosystem, its organic matter recycling capabilities are beneficial.

The population of the Cichlid *T. simonis simonis* is presently in serious decline, but our sampling confirmed the existence of a high concentration of YOY fingerlings. Feeding trait is considered as bottom dwelling.

Food item collection by *N. leantinae* is indicated as stone scraping whilst no Plankton (Phyt. & Zoop.) fragments were documented.

3.3. Food Composition—Location and Beach Vegetation

The potential linkage between gut content composition and vegetation cover or bottom type affinity was suspected. Therefore, gut content compositions of all individuals and all species sampled in a site were pooled together for site comparison (**Table 10**) and combined with plant cover level information [10].

3.4. Commercial Harvest of Kinneret Native Tilapias

Kinneret annual landings averaged (±SD) for 8 decades (Table 1) of three native fish species are given in Table 12.

Fishing motivation and, consequently, effort investment depend solely on market demands. Therefore, precaution should be accounted for the evaluation of relating stock assessment to commercial landings. During 2007-2011, a significant decline of *S. galilaeus* harvest was documented and similar decline timing was indicated for *T. simonis* and Bleaks. Among those three species, much higher fishing motivation is given to *S. galilaeus* and *T. simonis* than to Bleak of which fishing is purely determined by market demand. Consequently, the decline of the Tilapias can be attributed to environmental conditions' deterioration whilst that of Bleak to fishing effort reduction. ANOVA Test ($p < 0.05$) in-between decade averaged landings indicated significant ($p < 0.0001$) lower landing in decades 7 and 8 for the three species (Table 11 and Table 12). It has to be considered that during 2006-2016 beach inundated vegetation was extremely developed, creating a vast space of refuge for fingerlings but landings decline was documented. The WL decline probably narrowed the space of the optimal bottom belt with suitable granulometric composition for Tilapia reproduction (nest construction).

4. Discussion

The history of human intervention (anthropogenic management) in the management of the Lake Kinneret ecosystem started in 1933 when the South Dam (Deganiya Dam) was constructed. Earlier (1918), a wooden bridge located at the outlet site of the river outlet was constructed. The 1918 bridging between the two river banks did not modify the Lake's natural conditions of water budget or rate of exchange. The south dam construction granted partial control of water ba-

Table 11. Air Photo documented Beach Vegetation cover is classified into three levels: 1) Dense cover (45% of the entire beach belt); 2) Dispersed cover (15% of the entire beach belt); 3) Un-covered (39% of the entire beach belt) [10]. Food components that were documented in all 5 fingerlings that were sampled in those sites (1 - 10) (See Material and Methods).

Station No., Name	Food Component documented in all 5 dissected specimen	Plant Cover
1: Biriniki	Detritus, Microcystis, Tubifex, Harpacticoids, Chironomids, Fish scales, Butterfly Scales, Sand Grains	un-covered
2,3, 6: Migdal, Ginosar, Arbel	Harpacticoids, Plant Debris, Detritus, Diatoms-Penales, Spiculae-Porifera, Sand Grains, Filamentous Cyanophytes, Chydorus, Foraminifera, Zooplankton Fragments	Dense-Dispersed
4: Ohalo	Amorphic silt particles, Copepods Fecal Pellets, Cyclopoid Fragments, Sand Grains, Tintinids, Plant Debris, Nematodes, Chironomids, Diatoms-Penales, fragments of Terrestrial Insects,	Dense-Dispersed
5: Lido	Diatoms-Penales, Spiculae-Porifera, Bazalt Grains, Sand Grains, Plant Debris, Tubifex, Filamentous Cyanophytes,Diatoms-Penales, Fragilaria.	Un-covered
7: Amnon Bay	Detritus, Microcystis, Plant Debris, Epiphytic Chlorophytes, Oscilatoria, Diatoms-Penales, Brachionids, Ostrcod Shells, Aulacoseira Fragments, Foraminifera, Spiculae-Porifera, Chironomids, Sand Grains, Butterfly Scale, Zooplankton Fragments.	Dispersed
8: Maagan	Melanoides Shell, Sand Grain.	Dense
9, 10: Ein-gev	Chironomid, Sand Grains, Bazalt Grain.	Dispersed

Table 12. Decades (See **Table 1**) mean (± SD) landing harvests of Bleaks, *S. galilaeus* and *Tristramella simonis simonis* (tons). SD = 0 insufficient data record.

Decade	*S. galilaeus.*	*Tristramella simonis*	Bleak
3	166 (0)	126 (0)	952 (0)
4	167 (26)	156 (24)	1023 (50)
5	228 (44)	172 (39)	1002 (67)
6	356 (123)	189 (68)	967 (258))
7	272 (136)	83 (49)	861 (282)
8	99 (86)	8 (9)	173 (198)

lance and consequently Water Residence Time (WRT) and Water Level Altitude (WLA) and several other consequences. Nevertheless, lake utilization constraints became crucial after several additional anthropogenic operations: 1) The construction of the National Water Carrier (NWC) was the result of the national water supply program of daily transportation of 1×10^6 m^3 (MCM) of water to the southern part of the country; 2) Fishery legislations and introduction, including exotic species; 3) regulations of housing and recreational usage of the beach surface area. Optimization of Kinneret Ecological Services requires integration of all implemented constraints. These inputs ultimately require being formulated towards optimal design, aimed at a reasonable quality of water for domestic supply, fisher income, sufficient suitability of the beach surface for recreation, housing constructions and tourism. One of the cardinal issues is water level regime. It was documented that a water level above 212 mbsl creates a bottom surface at a preferable depth (0.5 - 3.0 m) suitable for nest builder Tilapias whilst at lower WL the bottom sediment belt area at same water depth is sub-optimal for nesters. Moreover, long-term high ranged (annually > 2 m) fluctuations of WL below and above 212.5 MBSL create seasonal inundation of shoreline zone enabling dense vegetation to be developed. This development of beach vegetation improves sheltered habitat-forming for YOY fingerling refuge. The disadvantage of exceptionally low WL is unsuitable bottom substrate less favored by nest builder Tilapias. The advantage of low WL is the developed beach vegetation supporting sheltered refuge for the new-born offspring after being released from parents mouth nursery. It has to be considered that there is dissimilarity among Tilapia species in bottom substrate preference as a nesting ground. Nest construction by *Coptodon (Tilapia) zillii* is adapted to the substrate conditions by producing 5 different nest structure [15]. Unlike *C. zillii*, the commercial species of Tilapia, *S. galilaeus, O. aureus* and *T. simonis simonis* construct nests in open surface and macrophyte free bottom substrate. The nest constructor, male and female couple of *O. aureus*, creates a deep (15 - 25 cm) funnel with upper round shape open in a stable substrate of silt-sandy ground. These densely distributed "funnels" stay intact when WL declines and their upper part is exposed but with water still filling the lower part of the nest, providing the newborn offspring with a sheltered refuge. Couple, male and female, of *S.*

galilaeus, on the contrary, construct nest as a shallow depression (saucer like 40 - 75 cm in diameter) when both, removed by their mouth course particles aside, [17] even great empty mollusk (bivalves, gastropods) shells. The egg laying, sperm ejection and fertilization occur immediately, and shortly after that the nest is usually deformed by wave action [16]. When WL level decline, no remains of *S. galilaeus* nest can be observed and the nests do not keep along intact like those of *O. aureus*. The dimensions of 20 "Funnel" type nest of *C. zillii* were measured during May-June 1987 [18]: the depth of the nests varied between 13 - 30 cm and the uppermost diameter was between 30 - 100 cm, covered by a water layer of 20 - 80 cm. The density of the nests in a sandy bottom was 79 along 26 m. There were plants within the nesting ground. Ben-Tuvia *et al.* [18] documented nest constructions of *O. aureus* and *S. galilaeus* in sandy bottom habitat partly protected from the wave action impact but sparsely plant covered or mostly uncovered. Nevertheless, Tilapia spawners were abundant in the shadowed waters under Tamarix trees. Consequently, it is suggested that bare sandy bottom is preferably selected by tilapias for spawning and nest constructing and aquatic space beneath Tamarix trees is utilized during in-mouth egg-incubation and larval accommodating. The nest ground preference by *O. aureus* is sandy and not plant covered, with an uppermost diameter of about 100 cm. Eliminating constraints of water supply, optimal management of WL aimed at improving reproduction of *S. galilaeus* spawning is recommended to be annually fluctuated with maximal range between 211.50 and 213.50 MBSL. The higher WL altitude is accompanied by the appropriate bottom substrate, and the lower altitude enhance beach vegetation growth, ensuring fingerling refuge. Nevertheless, the enhanced beach vegetation is a recreational nuisance which requires the partial anthropogenic intervention of plant mowing. It is not recommended to keep long-term high WL by close dam policy which is indicated as enlarged residence time known as a Eutrophication factor.

Results presented in **Tables 3-11** indicate the bottom feeding trait of fingerlings in the Kinneret Littoral habitat. Unlike filter feeding fishes, the YOY fingerlings collect their food items either by active dwelling in the uppermost bottom surface layer or by occasionally collecting suspended particles as a result of wave action re-suspension.

Vegetation, WLF, and Fingerling Abundance

Until late the 1990's WL fluctuated mostly around 212 MBSL. The result was continuity of water cover of the half-open lagoons in the Beteicha valley connected to the north-east shoreline of lake Kinneret. This lagoon area was highly populated by Tilapia spawners [15] [19] [20]. Surveys carried out in the littoral zone of Lake Kinneret during the late 1980's [18] indicated high densities of fingerlings in the shallows with not significantly linked to vegetation. About 100 - 131 Fingerlings (1 - 10 cm TL) of *C. zillii* were captured by Electro-Shocker in a shallow water area, not plant covered, of 5 - 10 m^2 within 10 - 15 minutes [18]. Long-term decline of WL below 212.50 caused a complete elimination of Tilapias and other species production from the Beteicha lagoon region. Moreover, suitable substrate belt along the entire shoreline was restricted as well. The production capacity of *O. aureus* and *S. galilaeus* was therefore damaged under lower WL but that of *C. zillii* was not damaged. Reduction of production capacity might be partly tackled by anthropogenic activity such as stocking enhancement, elimination of Birds predation and appropriate fishing legislations.

It is suggested that WL fluctuations (high values of WLFI) affected the production of Tilapias in Lake Kinneret by frequent changes of bottom suitability for nest construction, which indeed logically makes sense. Nevertheless, results presented in this paper do not confirm it. If landings reflect production successes, the decline of *S. galilaeus* annual harvest was correlated with WL long-term decrease and not short-term fluctuations. The index of WL fluctuation which reflect the amplitude of annual changes was high in decades when WL was high (1946-1955; 1965-1976) and low as well (2006-2016). High values of Index of WLF when WL amplitude is high is not significantly affecting nest builder tilapias. On the contrary, when WLFI is high during low altitude, Production is suppressed and consequently the commercial harvest. The decline of nest builder-mouth-breeder Tilapias during the 8th decade (2006-2016) is due to a lack of optimal bottom substrate area and not because of insufficient submerged plant-mediated fingerling refuge [20]. Food resources for fingerlings as reported in the present study were sufficient. The reduction of Tilapia Production capacity might be overcome by stocking. Fisheries data confirm the linkage between low harvest and long-term low WL (**Table 13** and **Table 14**). These relations validate the negative impact of unsuitable bottom substrate influence on

Table 13. Annual (2000-2015) landings (ton) of Sarotherodon galilaeus, Tritramellids simonies, Bleaks and Total (all species).

Total (ton)	Bleak (ton)	Tristramella simonis. (ton)	S.galilkaeus (ton)	year
1851	1052	52	262	2000
1286	811	24	110	2001
1569	1123	23	93	2002
1064	641	13	91	2003
1137	422	22	237	2004
1335	558	76	316	2005
1297	545	1	151	2006
84	439	6	51	2007
224	88	1	8	2008
401	98	3	20	2009
389	19	12	45	2010
461	44	3	62	2011
955	266	7	166	2012
347	38	1	116	2013
517	21	2	275	2014
501	39	1	325	2015

Table 14. Decade Averages of the Kinneret monthly Water Level (MBSL) means.

Decade	Months Counted	WL (MBSL)
1936-1945	118	210.63
1946-1955	115	210.42
1956-1965	120	209.77
1966-1975	120	209.79
1976-1985	120	210.14
1986-1995	120	210.53
1996-2005	120	211.75
2006-2016	132	212.43

Tilapias production. Moreover, the partial elimination of inundated beach vegetation factor as production improvement for Tilapia is justified. The attempt is done to establish a linkage between beach vegetation and fingerling density is, therefore, corroborated [18]. Conclusively, it can be remarked that fingerling density and inundated beach vegetation are not strongly bounded factors.

5. Summary

The causation of environmental constraints on the Kinneret littoral ecosystem processes was analyzed. Among environmental factors, Water Level Fluctuations, inundated beach vegetation and food resources for fingerlings were considered. The potential influence of water Level and spawning ground availability and quality were indicated when the level is in extreme decline but can be confounded by fishery regulations and stocking program. The dominant impact of marketing capacity on the landing crops of Bleaks was confirmed. It is concluded that sufficient food for fingerlings exists in the Kinneret shallows and a lack of refuge condition, *i.e.* inundated vegetation, has no significant influence on fingerling survival.

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