Impact of purifying aquatic environment on *Tilapia zillii* production quality, caught from Lake Mariout, Egypt. Challenges and solutions!

[1]Amal F. Fahmy, [2]Nawal A. El-Ghazaly, [2]Abdo-allah Sayed, [3]Kholoud Areef

[1] Aquaculture Division, National Institute of Oceanography & Fisheries (NIOF), Alexandria, Egypt; [2] Zoology Division, Faculty of Science, Alexandria University, Egypt; [3] Zoology Division, Faculty of Science, Omar Al-Mukhtar University, Bayda city, Lybia.
Corresponding author: A. F. Fahmy, aml.fayez2017@gmail.com

Abstract. The successful management of the environment and choice of tilapia broodstock are important keys to seed quality sustainability. Lake Mariout receives untreated or poorly treated industrial and agriculture effluent wastes that accumulate in aquatic animals. Wastes, as Zn, Cu, and Cd, affect the spawning performance and seed quality (eggs and larvae) of tilapia fish. This study was conducted to assess the spawning performance and seed quality, under controlled laboratory conditions and overcome the negative effects of lake contamination on *Tilapia zillii* broodstock. Mature *T. zillii* were selected from two different polluted sites in the main basin of Lake Mariout during the pre-spawning season. These specimens were cultured in clean brackish water (5 ‰ salinity) from April to June 2017. Heavy metals were analyzed in all successive egg batches from broodstock caught at the two sites. The results indicated that, according to the broodstock origin, the first egg batch had high heavy metal concentrations that adversely affected the egg and larval quality. Highly significant positive differences ($p < 0.01$) were observed in the egg and larval quality in the successive batches during the purification period in clean brackish water of both sites. Seed qualities were positively influenced at the end of the purification period. The study concluded that controlled aquatic environment (purification period) had a positive impact on seed quality production. It proved that the deleterious effects of heavy metal concentrations on broodstock production is a reversible process.
Key Words: seeds quality, heavy metals, *Tilapia zillii,* Lake Mariout, water contamination.

Introduction. Tilapia is an important source of protein for developing countries that help in food security. *Tilapia zillii* is a suitable species for commercial fish culture and constitutes 70% of Egypt's fish production Canonico et al (2005). Ibrahim & Ramzy (2013) found that *Tilapia zillii* was affected severely by industrial and agricultural discharge wastes, which is a major problem in aquaculture in Egyptian Lakes.

Lake Mariout is a brackish lake in northern Egypt and forms the southeast border of Alexandria city. The main basin of Lake Mariout is affected by a direct drain of industrial effluent mixtures, sewage, domestic wastes and agricultural drainage discharges (Mateo 2009). Lake Mariout has changed from being the most productive fisheries resources of the four major Egyptian brackish water lakes to the least productive in a couple of decades (El Zokm et al 2018).

Water contamination with heavy metals has been a worldwide problem that induced reduced spawning or damaged nursery areas for fish stocks with acute or chronic toxic impacts on fish life (Elsaim et al 2018; Azab et al 2019). Environmental pollution correlates with heavy metal concentrations and the time of exposure (Jezierska et al 2009). Gautam & Chaube (2018) found that the percentage of broodstock ovulation increased with low concentration of heavy metals in the water. Dietrich et al (2011) found that some heavy metals disrupt many reproductive processes in fish such as maturation, fertilization success, and embryonic and post-embryonic development. Velcheva (2006) established the correlation between the heavy metal levels in the water and those in fish. Several authors have studied the metal deposition in the fish gonads and its adverse effects on seed production and embryonic development (Hallare et al

2005; Ługowska 2005; Fraysse et al 2006). Pandey & Madhuri (2014) studied the impact of heavy metal concentrations on fish growth, fitness, development, hatching glands function and the onset of exogenous feeding.

The controlled aquatic environment may be used to improve fish production in a duration-dependent manner. Therefore, this study aims to highlight the negative impact of heavy metal accumulation and to demonstrate the reversible positive impact of a controlled period of aquatic environment purication on the quality of *T. zillii* production.

Material and Method

Area of study. Lake Mariout is a brackish lake and it lies at the north of the Nile Delta, southeast of Alexandria. It is one of the main fishing grounds of Alexandria located between longitude 29°47.1′ to 29°50.4′ E and latitude 31°7.5′ to 31°9′ N. The lake is divided into four basins. The main basin of Lake Mariout subjected to the direct discharges and pollution loadings coming from the industrial and agricultural drains. The two study sites were inshore site near the industrial and agriculture drainage and the offshore, a fishing area, with different degrees of pollution in the main basin of Lake Mariout (Figure 1).

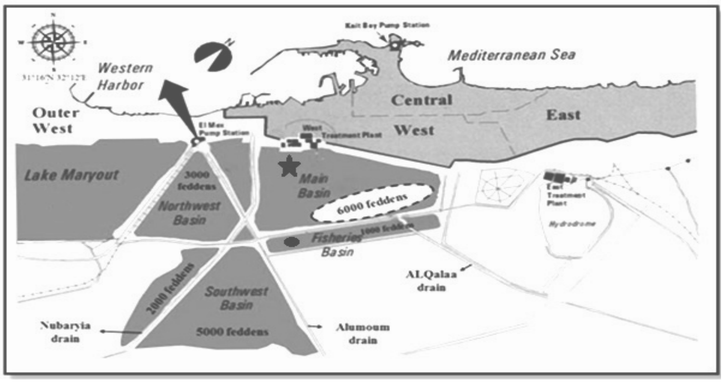

Figure 1. Location of sampling sites in Lake Mariout:
★Inshore site; ●Offshore site.

Broodstock selection. Broodstock were caught by fishing net at each sampling site in the spawning season of the *T. zillii*. In April 2017, eighty sexually mature samples of both sexes (100-150 gm) were collected from the two different sites of Lake Mariout. Sexually mature samples were labeled and transported with aerated containers to the research unit in the hatchery of the National Institute of Oceanography and Fisheries (NIOF), Alexandria, Egypt.

Acclimatization of the broodstock. In the research unit, under controlled laboratory conditions, broodstock from each site were transferred to fiberglass tanks for each site (250 × 100 × 50 cm), 250 L-capacity. These tanks were filled with de-chlorinated tap clean water and added seawater to reach natural brackish water in Lake Mariout (5‰ salinity). The acclimatization period was during April 2017 while the observational period extended throughout 60 days (May to June 2017). Fish were fed with a 25% crude protein diet at 5% mean body weight once a day with commercial dry pellets. The feces and all uneaten food were siphoned out daily and water tanks were filtered to improve water quality.

Broodstock management and spawning. During the acclimatization period, mature males and females were stocked separately and cultured in two triplicate spawning tanks. In May, they were placed together with sex ratio 1:3 (male: female). Each trial was kept together until spawning occurred. During May month, there was no sign of broodstock spawning from the two different polluted sites. In June, spawning was checked from each tank and the spawning batches were observed once every 10 days and all fertilized eggs and newly hatched larvae were allowed to develop further under optimized conditions until the onset of active feeding. Two-third of the water in each tank were renewed manually every 2 days and salinity adjusted.

***Sample analysis**.* Samples of egg batches from each broodstock were collected for heavy metal analysis; Zn, Cu, and Cd. Atomic Absorption Spectrometer (AAS-6800, SHIMADZU, Japan) was used according to the method described by Kalay et al (1999). The results from the AAS were expressed as μg g^{-1} dry weight and converted to mg kg^{-1}.

Biometric indices

Egg diameters and numbers of successive egg batches of broodstock caught from inshore and offshore sites. All fertilized eggs spawned were collected from the tanks of the two sites; egg diameters and number from each site were measured and placed in small 50 liters aerated aquaria. As for the spawning frequency, the number of spawning per female was assessed every 10 days during the observational period.

Egg quality of successive egg batches of the broodstock caught from inshore and offshore sites. Samples of egg quality of successive egg batches of the broodstock caught from inshore and offshore sites were calculated. Egg quality parameters included: fertilization and hatching rate, hatching time, the survival rate of newly hatched larvae and the onset of exogenous feeding.

Larval quality and yolk sac characteristics. Larval quality and yolk sac characteristics from broodstock caught from inshore and offshore sites were evaluated. The newly hatched larvae from each site were transferred to 50 liters aerated aquaria. The larvae were counted daily (dead larvae were also counted and removed) and transferred to a clean aquarium with fresh brackish water. Larvae were not fed during the observational period as they still possessed endogenous yolk reserves. Larval measurements follows: larval length (mm), yolk sac diameters (mm) and yolk utilization were calculated until the onset of exogenous feeding. Yolk utilization was calculated by the differences between yolk sac diameters of the newly hatched larva and yolk sac diameters of the five days post hatching (5 DPH).

***Statistical analysis**.* All statistical analyses were calculated using the computer program SPSS Inc. (2001, version 11.0 for Windows) at the 0.01 level of significance. Two-way ANOVA was used to find the significant differences of heavy metal concentrations in egg batches and larval between the different batches of the same site as well as the same batch of different sites.

Results

Heavy metal concentrations of successive egg batches of broodstock caught from inshore and offshore sites. Heavy metals concentrations (Zn, Cu, Cd) of the successive egg batches of *T. zillii* broodstock caught from inshore and offshore sites are shown in Table 1. Heavy metals concentrations affected the numbers of the broodstock spawning frequency (number of batches). Broodstock caught from inshore site spawned three successive batches compared to others from the offshore site that spawned only two successive batches. The heavy metals concentrations of the first egg batch were significantly higher ($p < 0.01$) in both sites regarding the broodstock origin. There were significant differences in the mean heavy metal concentrations in the first egg batch in both sites. During the period of purification, there were gradual decreases in the heavy metal concentrations of successive egg batches in both sites.

Table 1

Mean concentration of heavy metals (mg kg^{-1}) of the successive spawning batches of *T. zillii* caught from two different sample sites from Lake Mariout and the permissible limit in fish

Spawning frequency	*1st batch (n = 9)*	*2nd batch (n = 9)*	*3rd batch (n = 9)*	*Test of sig.*	*p*	*WHO (1992)*	*Wyse et al (2003)*
Zn							
Inshore	99.50^{a}±0.39	47.06^{b}±1.02	27.08^{c}±0.96	F=1729.97*	<0.001*	50	-
Offshore	52.91±1.11	34.50±0.38	-	t=15.136*	<0.001*		
(p_1)	(<0.001*)	(<0.001*)	-				
Cu							
Inshore	4.99^{a}±0.22	3.43^{b}±0.13	2.66^{c}±0.21	F=112.77*	<0.001*	30	3.28
Offshore	4.63±0.25	3.20±0.14	-	t=6.521*	<0.001*		
(p_1)	(0.295)	(0.255)	-				
Cd							
Inshore	1.78^{a}±0.13	0.95^{b}±0.01	0.39^{c}±0.01	F=104.39*	<0.001*	2	0.18
Offshore	0.54±0.05	0.40±0.02	-	t=2.332*	0.048*		
(p_1)	(<0.001*)	(<0.001*)	-				

p_1: p value for comparing between Inshore and Offshore in each batch; F: F test (ANOVA) with repeated measures, significant between periods was done using Post Hoc Test; t: paired t-test; p: p value for comparing between the three batches from each site; Means with common letters are not significant (i.e. means with different letters are significant).

Heavy metal concentrations on the production quality of broodstock caught from inshore and offshore sites

Biometric variations of egg diameters and numbers. The variability of egg diameters and numbers of the successive egg batches in the same site and between two different studied sites are shown in Table 2. There were highly significant differences ($p \leq 0.01$) in the egg diameters between both sites and between three successive batches at the inshore site. However, there was no significant difference ($p \geq 0.01$) in the egg diameters between the successive batches at the offshore site. Furthermore, there was a progressive increase in the fecundity (egg numbers spawned per female) of successive egg batches with highly significant differences ($p \leq 0.01$) between different sites and successive egg batches. Moreover, there was a strong negative correlation between egg diameters and numbers in both sites.

Table 2

The diameters and number eggs spawned in the successive spawning batches of *T. zillii* caught from two different sample sites from Lake Mariout

	1st batch (n = 9)	*2nd batch (n = 9)*	*3rd batch (n = 9)*	*Test of sig.*	*p*
Egg diameter (mm)					
Inshore	1.74^{a}±0.05	1.67^{a}±0.05	1.41^{b}±0.2	F=22.91*	<0.001*
r	-0.78*	-0.65*	-0.94*		
Offshore	1.39±0.01	1.34±0.5	-	t=1.353	0.213
r	- 0.89*	-0.97*	-		
t_1(p_1)	6.406*(<0.001*)	5.174*(<0.001*)	-		
No. of spawned eggs					
Inshore	620.0^{a}±0.88	625.0^{ab}±2.25	630.0^{b}±3.15	F=6.034*	0.011*
Offshore	250.0±3.22	320.0±18.42	-	t=4.127*	0.003*
t_1(p_1)	110.724*(<0.001*)	16.436*(<0.001*)	-		

t_1: Student t-test; p_1: p value for comparing between inshore and offshore in each batch; F: F test (ANOVA) with repeated measures, significant between periods was done using Post Hoc Test (adjusted Bonferroni); t: paired t-test; p: p value for comparing between the three batches from each site; Means with common letters are not significant (i.e. means with different letters are significant); r: correlation between egg diameters and numbers in both sites.

Batches quality. There was a highly significant difference ($p < 0.001$) between heavy metals concentrations of the successive batches and the batches quality (Table 3). The first batch at the inshore site showed significantly decreased quality as compared to those from the offshore site. At the end of the observation period, progressive increases in the batch quality were observed in both sites. There were significant differences ($p < 0.01$) of the fertilization rate, hatching rate, hatching time and start of feeding time in successive batches and both sites.

Table 3

The batches quality in the successive spawning batches of *T. zillii* caught from two different sample sites from Lake Mariout

	1st batch (n = 9)	*2nd batch (n = 9)*	*3rd batch (n = 9)*	*Test of sig.*	*p*
% Fertilization					
Inshore	$76.50^{c}±0.90$	$79.50^{b}±0.76$	$86.75^{a}±0.60$	$F=76.41^{*}$	$<0.001^{*}$
Offshore	88.0±0.62	89.25±0.43	-	t=1.221	0.257
$t_1(p_1)$	$10.522^{*}(<0.001^{*})$	$11.105^{*}(<0.001^{*})$	-		
% Hatching					
Inshore	$65.25^{c}±0.70$	$68.44^{b}±0.60$	$79.0^{a}±0.63$	$F=195.97^{*}$	$<0.001^{*}$
Offshore	76.50±0.69	79.0±0.63	-	t=2.218	0.057
$t_1(p_1)$	$11.451^{*}(<0.001^{*})$	$12.116^{*}(<0.001^{*})$	-		
% Survival					
Inshore	$45.63^{b}±0.71$	$46.11^{b}±0.26$	$83.63^{a}±0.97$	$F=1784.9^{*}$	$<0.001^{*}$
Offshore	79.75±0.68	82.25±0.64	-	t=2.080	0.071
$t_1(p_1)$	$34.765^{*}(<0.001^{*})$	$52.292^{*}(<0.001^{*})$	-		
Hatching time					
Inshore	$28.75^{c}±1.35$	$47.25^{b}±1.53$	$70.25^{a}±0.74$	$F=455.4^{*}$	$<0.001^{*}$
Offshore	57.75±1.02	66.44±1.14	-	t=4.394	0.002^{*}
$t_1(p_1)$	$17.103^{*}(<0.001^{*})$	$10.074^{*}(<0.001^{*})$	-		
First feed (hrs)					
Inshore	$74.12^{c}±1.05$	$100.38^{b}±0.85$	$127.75^{a}±0.46$	$F=1226.2^{*}$	$<0.001^{*}$
Offshore	115.14±1.30	128.25±2.20	-	$t=3.030^{*}$	0.016^{*}
$t_1(p_1)$	$10.074^{*}(<0.001^{*})$	$2.495^{*}(0.031^{*})$	-		

t_1: Student t-test; p_1: p value for comparing between Inshore and Offshore in each batch; F: F test (ANOVA) with repeated measures, significant between periods was done using Post Hoc Test (adjusted Bonferroni); t: paired t-test; p: p value for comparing between the three batches from each site; Means with common letters are not significant, i.e. means with different letters are significant.

Larval quality under laboratory condition

Larval development. The differences in larval lengths that resulted from successive egg batches in both sites are showed in Table 4. There were significant differences ($p < 0.01$) of heavy metals concentrations of the successive batches; and larval length between both sites. Highly significant differences ($p < 0.01$) between heavy metals concentrations of egg batches and larval length at the inshore site, newly hatched larvae, were observed. The most affected batch was the first egg batch from the inshore site characterized by early hatching larvae and small length.

Larval yolk sac diameters and yolk utilization. The variation of the yolk sac diameters and yolk utilization (metabolism) of the developed larvae from successive batches in both sites are shown in Table 5. During the purification period, yolk sac diameters decreased significantly during larval development in both sites ($p \leq 0.01$). Furthermore, the yolk utilization of the developed larvae increased significantly during larval development in both sites ($p \leq 0.01$). The most affected larvae were those developed from the first batch and characterized with small lengths with large yolk-sac sizes (poor utilization of yolk nutrients). On the other hand, in the last batches, it was observed that the larval has increased length with smaller yolk-sac sizes and good utilization of yolk nutrients.

Table 4

The larval length in the successive spawning batches of *T. zillii* caught from two different sample sites from Lake Mariout

Larval length (mm)	*1st batch (mm)*	*2nd batch (mm)*	*3rd batch (mm)*	*p*
Newly hatched larvae				
Inshore	2.9±0.11[c]	3.43±0.6[b]	3.90±0.32[b]	<0.01*
Offshore	3.5±0.52	3.7±0.3	-	0.157
(p1)	(<0.01*)	(<0.01*)		
1 DPH				
Inshore	3.2±0.42[c]	3.7±0.29[b]	4.5±0.3[a]	<0.01*
Offshore	3.5±0.6	4.1±0.2	-	0.050
(p1)	(<0.01*)	(<0.01*)		
2 DPH				
Inshore	3.5±0.14[c]	4.2±0.5[b]	4.9±0.4[a]	<0.01*
Offshore	3.8±0.27	4.5±0.31	-	0.041*
(p1)	(<0.01*)	0.06		
3 DPH				
Inshore	3.8±0.29[c]	4.5±0.6[b]	5.3±0.2[a]	0.01*
Offshore	4.2±0.19	4.8±0.3	-	0.002*
(p1)	(<0.01*)	0.05		
4 DPH				
Inshore	4.1±0.2[c]	4.8±0.29[b]	5.8±0.4[a]	<0.01*
Offshore	4.4±0.21	5.1±0.23		0.016*
(p1)	(<0.01*)	(<0.01*)		
5 DPH				
Inshore	4.5±0.3[c]	5.1±0.61[b]	6.1±0.3[a]	<0.01*
Offshore	4.8±0.83	5.3±0.24		0.02*
(p1)	(<0.01*)	(<0.01*)		
Ref: Omotosho (1988)	Initial length of newly hatched larvae: 3.43-3.64 mm; final length 6 DPH: 5.8 mm			

p_1: p value for comparing larval length between the different spawning batches from each site; t: paired t-test; p: p value for comparing larval length from different sites in each batch; Means with common letters are not significant (i.e. Means with different letters are significant).

Table 5

The yolk sac diameter in the successive spawning batches of *T. zillii* caught from two different sample sites from Lake Mariout

Yolk sac diameter (mm)	*1st batch (mm)*	*2nd batch (mm)*	*3rd batch (mm)*	*p*
Newly hatched larvae				
Inshore	1.62±0.2[a]	1.5±0.3[b]	1.41±0.32[c]	<0.01*
Offshore	1.55±0.09	1.45±0.1		<0.01*
P1	<0.01*	<0.01*		
1 DPH				
Inshore	1.60±0.31[a]	1.48±0.4[b]	1.35±0.14[c]	<0.01*
Offshore	1.53±0.42	1.41±0.3		<0.01*
P1	<0.01*	<0.01*		
2 DPH				
Inshore	1.58±0.6[a]	1.43±0.4[b]	1.31±0.27[c]	<0.01*
Offshore	1.48±0.71	1.38±0.3		<0.01*
P1	<0.01*	<0.01*		
3 DPH				
Inshore	1.55±0.7[a]	1.39±0.4[b]	1.28±0.32[c]	<0.01*
Offshore	1.45±0.2	1.35±0.3		<0.01*
P1	<0.01*	<0.01*		
4 DPH				
Inshore	1.52±0.7[a]	1.36±0.23[b]	1.25±0.21[c]	<0.01*
Offshore	1.42±0.6	1.32±0.17		<0.01*
P1	<0.01*	<0.01*		
5 DPH				
Inshore	1.48±0.7[a]	1.33±0.5[b]	1.19±0.17[c]	<0.01*
Offshore	1.40±0.4	1.28±0.3		<0.01*
P1	<0.01*	<0.01*		
Yolk utilization				
Inshore	0.14	0.17	0.22	
Offshore	0.15	0.17		
Ref: Omotosho (1988)	Newly hatched larvae: 1.5 mm; after 4 DPH: 0.56-0.94 mm			

p_1: p value for comparing yolk sac diameter during age between different spawning batches from each site; t: paired t-test; p: p value for comparing yolk sac diameter during age from different sites in each batch; Means with common letters are not significant (i.e. Means with different letters are significant).

Discussion. Heavy metal contamination of aquatic environment is a common worldwide issue. In the present study, the variations in the quality between successive egg batches in both test sites were demonstrated. These are expected to be related to spawner's origin. When broodstock were exposed to different polluted sites of the Lake, contaminants may have been deposited in spawner's gonads and consequently affect seed qualities. The results showed that the most pronounced decreased values of the heavy metal concentration were noticed in the samples collected from the last batch at each site. Hereby, strong evidence exists on the impact of the aquatic ecosystem on the tilapia production quality. This study pointed out that the first batch in the reproductive cycle was influenced by broodstock heavy metal exposure.

Elsaim et al (2018) and Azab et al (2019) both emphasized the effect of heavy metal on reduced spawning and on damaging nursery areas for fish stocks with acute or chronic toxic impacts on fish life. Ibrahim & Ramzy (2013) observed the adverse effect of the aquatic ecosystem on the fish or health and they found the impact of industrial and agriculture discharge wastes in Lake's area on *T. zillii* quality. Areef (2017) found that the impact of broodstock heavy metals exposure on egg batches were dependant on the concentration of these heavy metals in water samples of Lake Mariout. Also, Jezierska et al (2009) reported that poor eggs and larval quality results correlated with the metal concentration in water which is directly transferred to the fish embryonic development.

There was an inverse correlation between diameter and egg number in successive batches of both sites. This result echoes the result of Rurangwa et al (1998) who reported that the exposure of the broodstock to various heavy metals concentrations decreased the fecundity of fish populations, either indirectly via accumulation in the reproductive organs or directly by acting on sperm and ova that reduced quantity and quality and cause population decline. Also, Kjesbu et al (1996) pointed out that in poor or unfavorable conditions fish give priority to egg size rather than egg number. Moreover, Hsiao et al (1994) found that heavy metals accumulation in ovarian eggs may reduce the number of viable fertilized eggs while the later batches were characterized with a smaller ovulated egg size.

The study showed a significant reduction in the heavy metals concentrations in the successive batches with higher egg quality as survival and hatching success of embryonic developments. It was noted that larvae from 1st batch of the broodstock had earlier egg hatching than other larvae from the successive batches. It was also noted that heavy metal contamination not only disrupted egg quality but also was extended to the larval quality. The first egg batches from both sites may have been affected more due to the high contaminated food intake with high concentrations of heavy metals. The impaired first batch egg quality may be as a result of feeding on natural algal contaminated feed in the two sites. On the other hand, after transporting broodstock to the controlled laboratory conditions, the broodstock were fed on artificial commercial feed with 25% protein that probably impacted positively on the seed quality in the following batches.

The study showed a significant reduction in the heavy metals concentrations in the successive batches with higher egg quality as survival and hatching success of embryonic developments. It was noted that larvae from 1st batch of the broodstock earlier egg hatching than other eggs from the successive batches. It was noted that heavy metal contamination not only disrupts egg quality but also extends to the larval quality. Jezierska et al (2009) clarified the influence of the accumulated heavy metals in the egg batches on the hatching time. Similarly, Bulut et al (2008) found that a high level of Zn and Cd metals had negative effects on egg hatching.

The current study highlights the impact of the broodstock origin on the first egg batch. Afterwards, the larval lengths were also affected negatively due to heavy metal accumulation in first batch. Larvae displayed a reduction in length, with impaired yolk utilization due to the high Cd level in the first batch from the inshore site. Ługowska (2005) and Sikorska & Ługowska (2005) pointed out, the effect of toxicity levels of Cd on common carp (*Cyprinus carpio*) larval length reduction and retardation of yolk absorption which may lead to larvae death. Additionally, the measurements of the yolk sac diameters at the larval stage decreased significantly in this study during larval development in both sites that depended on the purification time. Sikorska & Wolnicki (2010) and Witeska et al (2014) observed the effect of the heavy metal toxification on a delay in the yolk sac absorption. Witeska et al (2010) explained the reduction of yolk utilization rate due to the presence of heavy metals accumulation that reduced the metabolic rate of larvae or from a direct effect on yolk itself. Likewise, McGeer et al (2000) studied the effect of heavy metal concentration as Cd and Zn on metabolic rate and concluded that the possible growth reduction by heavy metals may be due to their metabolic costs on detoxification. The observational study period showed that larvae spawned from the inshore site were characterized with a low yolk absorption rate possibly due to the presence of high Cd and Zn levels accumulated in the egg batch. Yolk utilization at the offshore site was higher than the inshore site. This is possibly due to the different concentrations of heavy metals that accumulated in fertilized eggs spawned from exposed parent fish. Heavy metals may have induced a direct effect on the broodstock gonads that influenced the larvae's metabolic functions expressed as large or deformed yolk sac larvae. A large yolk sac at hatching is due to premature hatching that shortened the entire embryonic development, consequently altering the early cleavage patterns and hatching time. Stasiūnaitė (1999) demonstrated the effect of the heavy metals concentrations on retarded yolk sac resorption of hatched *Oncorhynchus mykiss* larvae. The impact of culture controlled conditions in the present work was clear after successive spawning frequency as larval length increased with smaller yolk-sac sizes and good utilization of yolk nutrients.

The results of this study confirm that the seed qualities were positively influenced at the end of the test. This proves the positive impact of aquatic environment purification on the quality of *T. zillii* production. The study emphasizes the challenges of heavy metal toxicity on exposed broodstock production, seed quality, population size reduction, future reproduction. This has a major impact on one of the largest and important lakes of Egypt, Lake Mariout. It highlights the influence of an adequate period of aquatic environment purification under standardized conditions on tilapia spawning performance and seed quality production.

Conclusions and Recommendations. The impairment of tilapia spawning performance caused by heavy metal accumulation is not a permanent process. This work verifies that it is a reversible process and fish can recover their seed quality after an adequate period of purification. Despite the Egyptian government's efforts since 2009, this work shows that these efforts are not enough. Therefore, regular seasonal bio-monitoring may be a key challenge to consider the effects of heavy metals on the fish population to ensure the safety of environmental aquatic health. There is a serious need for developing a local database not only for Lake Mariout but for all Egyptian lakes. Early detection of altered quality of aquatic life environment is essential to mitigate the negative influence of environmental pollution and evaluate the potential risk of the aquatic lives in Lake Mariout. Regular monitoring and assessment of fishing sites are the essence to protect fish stock and consumer's health. This work encourages governments not only in Egypt but across the world to protect the aquatic environment and understand that the harmful effects of contamination/pollution to broodstock is a reversible process.

References

Areef K. A., 2017 Effect of bioaccumulation of some heavy metals on reproductive performance and larval quality in fish *Tilapia zillii* in Lake Mariout. MSc Thesis, Zoology Department, Alexandria University, 50 pp.

Azab A. M., Aly-Eldeen A., Khalaf-Allah MM., El-Battal M., 2019 Effect of heavy metals on the ovary of *Tilapia zillii* in some canals of Nile Delta area, Egypt. Egyptian Journal of Aquatic Biology and Fisheries 23(3):329-345.

Bulut M., Akbulut M., Ates A. S., Mendes M., 2008 Effects of some heavy metals on hatching of fertilized eggs in four marine fish species in Aliaga Bay (Eastern Aegean Sea), Turkey. Asian Journal of Chemistry 20(4):2603-2609.

Canonico G. C., Arthington A., McCrary J. K., Thieme M. L., 2005 The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems 15(5):463-483.
Dietrich M. A., Dietrich G. J., Hliwa P., Ciereszko A., 2011 Carp transferrin can protect spermatozoa against toxic effects of cadmium ions. Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology 153(4):422-429.
El Zokm G., Tadros H., Okbah M., Ibrahim G., 2018 Eutrophication assessment using TRIX and Carlson's indices in Lake Mariout Water, Egypt. Egyptian Journal of Aquatic Biology and Fisheries 22(5):331-349.
Elsaim M. H., Abd Elrhman A., Ali A., Jame R., 2018 Determination of Levels of Some Heavy Metals in Fish and Hens Eggs in Sudan. American Journal of Physical Chemistry 7(2):37-44.
Fraysse B., Mons R., Garric J., 2006 Development of a zebrafish 4-day embryo-larval bioassay to assess toxicity of chemicals. Ecotoxicology and Environmental Safety 63(2):253-267.
Gautam G. J., Chaube R., 2018 Differential effects of heavy metals (cadmium, cobalt, lead and mercury) on oocyte maturation and ovulation of the catfish *Heteropneustes fossilis*: an *in vitro* study. Turkish Journal of Fisheries and Aquatic Sciences 18(10):1205-1214.
Hallare A. V., Schirling M., Luckenbach T., Köhler H. R., Triebskorn R., 2005 Combined effects of temperature and cadmium on developmental parameters and biomarker responses in zebrafish (*Danio rerio*) embryos. Journal of Thermal Biology 30(1):7-17.
Hsiao S., Greeley Jr. M. S., Wallace R. A., 1994 Reproductive cycling in female *Fundulus heteroclitus*. The Biological Bulletin 186(3):271-284.
Ibrahim L. A., Ramzy E. M., 2013 Water quality and its impact on *Tilapia zillii* (case study) Qarun Lake-Egypt. International Water Technology Journal 3(4):170-191.
Jezierska B., Ługowska K., Witeska M., 2009 The effects of heavy metals on embryonic development of fish (a review). Fish Physiology and Biochemistry 35(4):625-640.
Kalay M., Ay O., Canli M., 1999 Heavy metal concentrations in fish tissues from the northeast Mediterranean Sea. Bulletin of Environmental Contamination and Toxicology 63(5):673-681.
Kjesbu O. S., Solemdal P., Bratland P., Fonn M., 1996 Variation in annual egg production in individual captive Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 53(3):610-620.
Ługowska K., 2005 [The effects of copper and cadmium on embryonic development, and quality of newly hatched common carp (*Cyprinus carpio* L.) larvae]. PhD Thesis, Academy of Podlasie, Siedlce, 127 pp. [in Polish]
Mateo M. A., 2009 Lake Mariout: an ecological assessment. Laura Serrano and Oscar Serrano (CEAB-CSIC), WADI Project (Water Demand Integration; INCOCT-2005-015226) and CEDARE (Centre for the Development of the Arabic Region).
McGeer J. C., Szebedinszky C., McDonald D. G., Wood C. M., 2000 Effects of chronic sublethal exposure to waterborne Cu, Cd or Zn in rainbow trout. 1: iono-regulatory disturbance and metabolic costs. Aquatic Toxicology 50(3):231-243.
Omotosho J. S., 1988 The development of eggs and larvae in *Tilapia zilliii* (Gervais). Nigerian Journal of Science 22(1-2):24-28.
Pandey G., Madhuri S., 2014 Heavy metals causing toxicity in animals and fishes. Research Journal of Animal, Veterinary and Fishery Sciences 2(2):17-23.
Rurangwa E., Roelants I., Huyskens G., Ebrahimi M., Kime D. E., Ollevier F., 1998 The minimum effective spermatozoa : egg ratio for artificial insemination and the effects of mercury on sperm motility and fertilization ability in *Clarias gariepinus*. Journal of Fish Biology 53(2):402-413.
Sikorska J., Ługowska K., 2005 [The effect of cadmium on embryonic development of common carp (*Cyprinus carpio* L.)]. Kom Ryb 3:6-8. [in Polish]
Sikorska J., Wolnicki J., 2010 Cadmium and copper toxicity to tench *Tinca tinca* (L.) larvae after a short-term exposure. Reviews in Fish Biology and Fisheries 20(3):417-423.

Stasiūnaitė P., 1999 Long-term heavy metal mixture toxicity to embryos and alevins of rainbow trout (*Oncorhynchus mykiss*). Acta Zoologica Lituanica 9(2):40-46.
Velcheva I. G., 2006 Zinc content in the organs and tissues of freshwater fish from the Kardjali and Studen Kladenets Dam Lakes in Bulgaria. Turkish Journal of Zoology 30(1):1-7.
Witeska M., Bilska K., Sarnowski P., 2010 Effects of copper and cadmium on growth and yolk utilization in barbel (*Barbus Barbus* L.) larvae. Polish Journal of Environmental Studies 19(1):227-230.
Witeska M., Sarnowski P., Lugowska K., Kowal E., 2014 The effects of cadmium and copper on embryonic and larval development of ide (*Leuciscus idus* L.). Fish Physiology and Biochemistry 40(1):151-163.
World Health Organization (WHO), 1992 Environmental health criteria 134: cadmium. World Health Organization, Geneva, 280 pp.
Wyse E. J., Azemard S., Mora, S. J., 2003 World-wide intercomparison exercise for the determination of trace elements and methyl-mercury in fish homogenate IAEA-407. International Atomic Energy Agency, Marine Environment Laboratory, Monaco 94 pp.

Received: 20 March 2020. Accepted: 12 May 2020. Published online: 27 May 2020.
Authors:
Amal F. Fahmy, Laboratory of Fish Reproduction and Spawning, Aquaculture Division, National Institute of Oceanography & Fisheries (NIOF), Kayet-bey Al-Anfoushy, Area Code 21556, Alexandria, Egypt, e-mail: aml.fayez2017@gmail.com
Nawal El-Ghazaly, Zoology Division, Faculty of Science, Alexandria University, El-Shatby station, Alexandria, Egypt
Abdo-allah Sayed, Zoology Division, Faculty of Science, Alexandria University, El-Shatby station, Alexandria, Egypt
Kholoud Areef, Zoology Division, Faculty of Science, Omar Al-Mukhtar University, Bayda city, Lybia, e-mail: prof_drkoloud@yahoo.com

How to cite this article:
Fahmy A. F., El-Ghazaly N. A., Sayed A., Areef K., 2020 Impact of purifying aquatic environment on *Tilapia zillii* production quality, caught from Lake Mariout, Egypt. Challenges and solutions! AACL Bioflux 13(3):1345-1354.