



A review on the breeding of Nile tilapia, *Oreochromis niloticus* in brackish water hatchery, Iran

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Abstract

Better management of tilapia hatcheries depends on effective factors on spawning and is affected by different factors. Nile tilapia *Oreochromis niloticus* were held at a water salinity of 11.5ppt, a temperature of $27\pm 0.5^{\circ}\text{C}$. Fish were fed a 40% protein food. Absolute fecundity varied between 50 and 2600 (mean 853 ± 25) eggs per clutch. Relative fecundity varied from 0.29 to 6.8 (mean 2.77 ± 0.13) eggs/g of female. Mean of wet weight of egg clutches was $4.98\pm 0.31\text{g}$ during the study period, increasing with size of female ($p<0.05$). Mean wet weight of each egg was $0.0062\pm 0.0001\text{g}$. Diameter of the eggs varied between 1.8 to 3.5mm and its mean was $2.58\pm 0.009\text{mm}$ increasing with average length and weight of spawners. The impact of sex ratio, stocking density, photoperiod, water salinity and replacement period on spawning performance of *Oreochromis niloticus* were investigated. Sex ratios 1:1, 1:4 and 1:7 (Male: Female), stocking densities 2, 3.5 and 5 fish/m³, photoperiods 6:18, 12:12 and 18:6 (Light: Dark) hours, water salinities 0, 4, 8 and 12 ppt, also 10- and 15-days replacement of breeders were studied. Fecundity, breeder and egg per day, spawning intervals, egg diameter and weight were investigated. Results showed stocking density 5 fish/m³, photoperiod 12:12 h, 8 ppt water salinity and 10 days replacement had better performance.

Keywords: Nile tilapia, Breeding, Brackish water, Iran

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Introduction

Tilapias are the second most farmed aquatic species in the world after carps. Tilapia is grown in more than 135 countries and its annual global production is more than 7.2 million tons. The production of Nile tilapia *Oreochromis niloticus* is more than 70% of all tilapias. In some countries, tilapia breeders are limited in their production of juveniles, and there is a large gap between the number of eggs and juveniles available and the demand of breeders. Tilapia seed producers are also usually faced with a number of constraints that limit the management of mass seed production [In: El-Sayed, 2006 (Little *et al.*, 1993; Bhujel, 2000)]. Therefore, optimizing the management of tilapia breeding hatcheries is essential for sustainable egg production and increasing breeding output. Tilapia sexual maturity and spawning performance resulted from different factors especially the total environmental approach, age and weight, stocking density, sex ratio and nutrition (Popma and Masser, 1999; Coward and Bromage, 2000; Tahoun *et al.*, 2008).

The establishment and selection of tilapia propagation system needs expert review. In this regard, it is necessary to particular consider regional characteristics, production program and investment purpose. Producers are the most important foundation of the reproduction workshop. It is very important to pay attention to the origin of the breeders and to maintain and stabilize the proper storage conditions in

the breeding workshop. Optimal spawning and artificial incubation of eggs increase the efficiency of the tilapia breeding. Proper reproduction efficiency can be achieved by using a suitable incubation system and establishing optimal conditions for the eggs to bloom and become floating juveniles and to improve the methods of preserving eggs and fries.

There are few investigations about reproductive biology of Nile tilapia in brackish water condition. Tilapia aquaculture is relatively new in Iran (Rajabipour, 2013). Reproduction of Nile tilapia in brackish water condition in Iran is studied (Mashaii, 2012 and 2016). The absolute and relative fecundity and spawning intervals of cultured *O. niloticus* in brackish water were measured. The optimum ranges for sex ratio, density, photoperiod, salinity and exchange periods of black female *O. niloticus* in brackish water are investigated as the effective factors for reproduction performance.

Materials and methods

Studies were performed in hatchery of National Research Center of Saline Water Aquatics in Bafq, at the center of Iran.

Nile tilapia (*Oreochromis niloticus*) broodfish were stocked at 5/m³ in six 3 m³ fiberglass tanks, during 15 months. Sex ratio was 1:3 (M: F). Elastomer tags were used for recognition of female fish. Water flow of the hatchery was a continuous 5 l/s. Water was constantly aerated to maintain dissolved oxygen saturation via a central air blower. Fish

were fed a 40% protein diet. Light regime was 18:6 (L:D) at 2,500 lux. Water salinity was about 11.5 ppt, water temperature, and pH was maintained at $27\pm 0.5^{\circ}\text{C}$, and 7.6–8.1, respectively.

Separate experiments conducted to investigate the density, sex ratio, photoperiod, salinity and exchange period of Nile tilapia, *Oreochromis niloticus* in brackish water with salinity 9.5 ± 0.5 ppt and Light regime was 12:12 (L:D). Each experiment lasted for 3 months. Breeders with 120-170 g mean weight were stocked in 2 m³ tanks in the experiments. To achieve the desired volume of water and the density storage in tanks, the height of drain pipe was set. For sex ratio experiment, breeders were stocked as 1:1, 1:4 and 1:7 (Male: Female). Stocking density of fish was 5 fish/m³, photoperiod 18: 6 (L:D). Two experiments were performed for stocking density of female breeders. In first experiment, stocking densities were as 2, 3.5 and 5 fish/m³ with sex ratio 1:3 (Male: Female). In the second experiment, the same treatments of stocking densities were considered with sex ratio 1:1. Photoperiod was 18: 6 (L:D) in both the experiments. Photoperiod treatments were 6:18, 12:12 and 18:6 hours (L:D). Resting periods of female breeders were investigated for 10- and 15-days periods. A control tank with the same stocking density and sex ratio was considered without resting period of the breeders. For salinity experiment, breeders were stocked in four different water salinities as 12 ± 0.5 , 8 ± 0.5 , 4 ± 0.5 and 0 ± 0.5 ppt. Water of 0 ppt, 4 ppt and 8 ppt salinities supplied

via water storage tanks. Water salinity of fish tanks was daily measured by a HQD Hatch portable refractometer. All treatments of the experiments had three replicates. For the photoperiod experiment, resting period and water salinity experiments, stocking density of the breeders was 5 fish/m³ and sex ratio 1:1.

Total body length and weight of females were recorded at each spawning event. Spawning intervals were recorded per female. Total eggs of each spawning female in each clutch were counted and weighted. Weight and diameter of at least 25 eggs from each clutch were measured. Data were compiled monthly. Absolute and relative fecundity were measured. Monthly means of egg size, wet weight of each egg and egg clutches were obtained. The number of spawner/day, egg/day, egg/spawner, egg/day/m³, mean length, weight and wet weight of eggs and mean of spawning intervals were obtained. Pearson correlation coefficients between total length and weight of brooders against absolute and relative fecundity, egg wet weight, egg clutch, and egg diameter were calculated and compared ($p < 0.05$). Monthly means of fecundity, egg diameter and weight obtained from different experiments were analyzed by one-way ANOVA, then compared between the treatments, by HSD Tukey and LSD tests ($p < 0.05$). Pearson's two-tailed correlation of means of fecundity, egg diameter and weight against sex ratio, stocking density, photoperiod and water salinity treatments were studied ($p < 0.05$). Independent samples t-test

was used to compare differences between reproductive parameters of salinity treatments ($p < 0.05$).

Results

Total length and weight frequencies of broodfish are shown in Figure 1. Mean weight of spawning females was 326.6 ± 163.37 g, with a mean total length of 26 ± 4.52 cm. Total length of the smallest *O. niloticus* spawned was 17

cm, and total weight 83.5 g. Spawning was infrequent in brooders larger than 500 g and essentially stopped when brooders reached 600 g. Female weight data for 13 spawns were not collected. Spawning intervals of the brooders varied between 16 and 34 days. Absolute fecundity varied between 50 and 2,600 (mean 853 ± 25) eggs per clutch. Relative fecundity varied from 0.29 to 6.8 (mean 2.77 ± 0.13) eggs/g of female (Fig. 2).

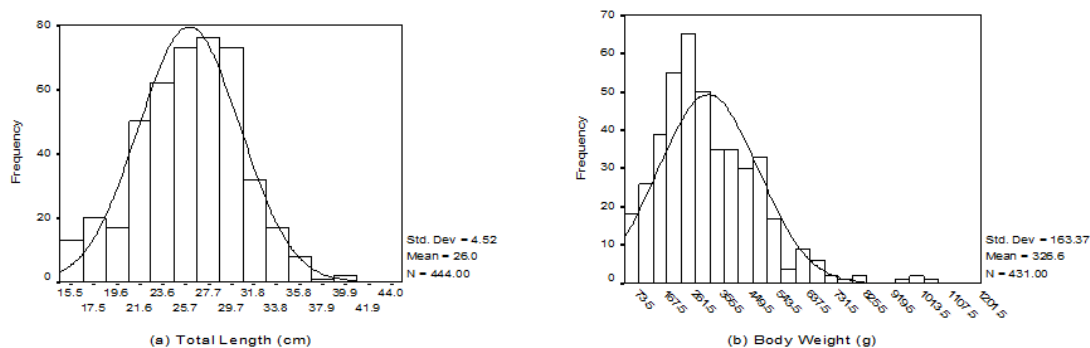


Figure 1: Total length (a) and body weight (b) frequencies of *O. niloticus* spawners.

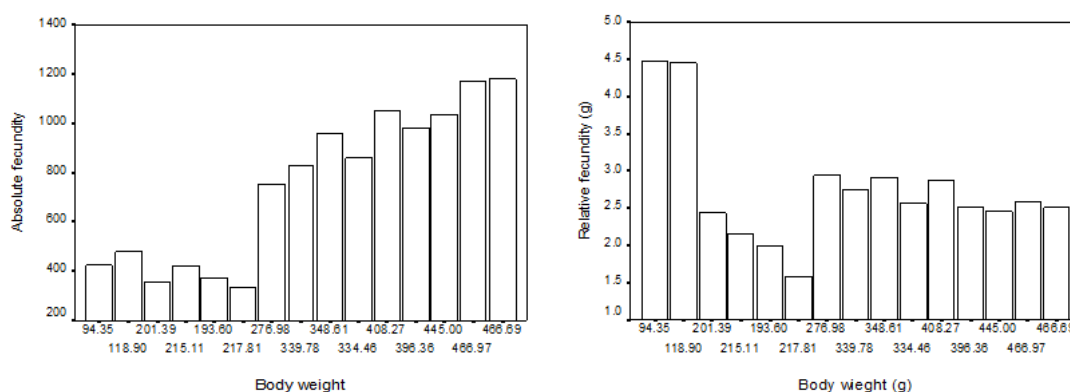


Figure 2: Variations of mean absolute (left) and relative (right) fecundity of *O. niloticus*.

Mean of wet weight of egg clutches was 4.98 ± 0.31 g during the study period, increasing with size of female ($p < 0.05$). Mean of wet egg weight was 0.0062 ± 0.0001 g. Means of wet weight of tilapia eggs gradually increased during the study period. Diameter of the

eggs varied between 1.8 and 3.5 mm, with a mean of 2.58 ± 0.009 mm, increasing with average length and weight of spawners. Pearson correlation coefficients showed significant positive correlation between total length and weight of the brooders with absolute

fecundity, wet egg weight, clutch size, and egg diameter ($p < 0.005$) (Table 1). Results of the sex ratio experiment as breeders were stocked 1:1, 1:4 and 1:7 (Male: Female) showed more fecundity and egg/day and shorter spawning intervals in the sex ratio 1:1 (Table 2). Means of fecundity were not

significantly different between sex ratios 1:1, 1:4 and 1:7 (Male: Female), by one way ANOVA and HSD Tukey test ($p > 0.05$). Two tailed Pearson correlation of sex ratio against fecundity was not significantly different ($p > 0.05$).

Table 1: Spawning parameters of *O. niloticus* in different sex ratios.

Sex ratio (M: F)	1:1	1:4	1:7
Mean fecundity \pm SE	712 \pm 49.4	613 \pm 45.5	641 \pm 54.7
Breeder/day	0.83	0.89	0.91
Egg/day	589	542	582
Egg/day/m ³	294.5	236.7	242.5
Mean spawning interval's (day)	20.2 \pm 6	29.2 \pm 11.5	27.6 \pm 10.9
Mean egg diameter \pm SE (mm)	2.97 \pm 0.03	2.93 \pm 0.03	2.89 \pm 0.02

Table 2: Two-tailed Pearson correlation of Absolute and Relative Fecundity Egg Weight Egg Clutch Weight and Egg Diameter against total length and body weight

		Absolute Fecundity	Relative Fecundity	Egg Weight	Clutch Weight	Egg Diameter
Total Length	Pearson Correlation	.565	-0.149	.739	.751	.662
	Sig. (2-tailed)	.0005**	0.004**	.0005**	.0005**	.0005**
	N	394	381	181	178	150
Body Weight	Pearson Correlation	.492	-0.233	.717	.692	.619
	Sig. (2-tailed)	.0005**	0.0005**	.0005**	.0005**	.0005**
	N	381	381	180	177	149

As the results of the stocking density experiment for 2, 3.5 and 5 fish/m³ with sex ratio 1:3 (Male: Female) showed, more fecundity and egg/day/m³ were higher in stocking density 2/m³. However, breeder/day, length, weight and wet weight of the eggs were higher in 5 fish/m³ along with shorter spawning intervals (Table 3). According to one way ANOVA and HSD Tukey test, there was no significant difference between the means of fecundity of the stocking density treatments ($p > 0.05$). Means of the egg diameter in 5 fish/m³ breeders were significantly higher than the other

stocking densities of the breeders, by HSD Tukey test ($p < 0.05$).

Results of the stocking density experiment for 2, 3.5 and 5 fish/m³ with sex ratio 1:1 (Male: Female) showed more egg/day, breeder/day, egg weight and diameter and shorter spawning intervals were obtained in stocking density 5 fish/m³. However, breeder/day, length, weight and wet weight of the eggs were higher in 5 breeders/m³ along with shorter spawning intervals (Table 4). One way ANOVA and HSD Tukey test showed no significant difference between the means of fecundities of the

treatments, however, means of the egg diameter were significantly higher in 5 fish/m³ than the other stocking densities of the breeders, by HSD Tukey test ($p < 0.05$). Two tailed Pearson correlation

of stocking density against fecundity was significantly different in both sex ratios 1:3 ($r = 0.149$, $p = 0.002$) and 1:1 ($r = 0.166$, $p = 0.004$).

Table 3: Spawning parameters of *O. niloticus* in different stocking densities, sex ratio 1:3.

Density (fish/m ³), sex ratio 1:3	2	3.5	5
Mean fecundity±SE breeder/day	846.4±80.9	620±75.4	593.7±61.9
Egg/day	325.6	306.7	327.3
Egg/day/m ³	162.8	133.6	136.4
Mean spawning intervals±SE (day)	22.4±6.9	23.1±4.6	19.2±9.3
Mean egg diameter±SE (mm)	2.933±0.03	2.954±0.02	3.29±0.02 ^{*H}
Mean egg weight±SE (g)	0.00832±0.0004	0.00825±0.0003	0.0119±0.003
Mean egg clutch weight±SE (g)	7.219±0.6	5.698±0.9	9.12±3.6

(*^H) shows significantly difference of means of the parameter between the treatment, by HSD Tukey test ($p < 0.05$).

Table 4: Spawning parameters of *O. niloticus* in different stocking densities, sex ratio 1:1.

Density (fish/m ³), sex ratio 1:1	2	3.5	5
Mean fecundity±SE Breeder/day	507±57.4	636±65.6	343±39.5
Egg/day	101.43	145.43	171.36
Egg/day/m ³	50.7	63.2	71.4
Mean spawning intervals±SE (day)	21.8±18.9	25.8±10.3	2.9±6.5
Mean egg diameter±SE (mm)	2.67±0.03	2.79±0.04	2.8±0.02 ^{*H}
Mean egg weight±SE (g)	0.0076±0.0004	0.0073±0.0004	0.0082±0.0003
Mean egg clutch weight±SE (g)	3.94±0.4	4.57±0.5	2.79±0.3

(*^H) shows significantly difference of means of the parameter between the treatment, by HSD Tukey test ($p < 0.05$).

Results of 12:12, 6:18 and 18:6 (L:D) photoperiod experiment for 5 fish/m³ with sex ratio 1:1 showed more fecundity in 18:6 (L:D) photoperiod. Higher breeder/day, egg/day, egg/day/m³, egg diameter and weight of egg clutch and lower spawning intervals were obtained in 12:12 photoperiod (Table 5). Means of fecundity, egg diameter and weight were not significantly different between 12:12, 6:18 and 18:6 (L:D) photoperiod, by

HSD Tukey test ($p > 0.05$). Two tailed Pearson correlation of photoperiod treatments against fecundity, egg diameter and weight were not significantly different ($p > 0.05$).

Table 5: Spawning parameters of *O. niloticus* in different photoperiods.

Photoperiod (L: D)	6:18	18:6	12:12
Mean fecundity±SE	475±58.3	391±54.5	438±41
Mean breeder/day	0.13	0.24	0.26
Egg/day	100	93	110
Egg/day/m ³	83.6	77.5	91.7
Mean spawning intervals±SE (day)	1906±5.3	21.7±6.5	20±6
Mean egg diameter±SE (mm)	2.78±0.04	2.81±0.04	2.83±0.02
Mean egg weight±SE (g)	0.01976±0.009	0.0201±0.007	0.0068±0.0003
Mean egg clutch weight±SE (g)	2.833±0.26	3.158±0.55	3.534±0.31

Resting periods of female breeders were investigated for 10 and 15 days and without resting period. 5 fish/m³ with sex ratio 1:1 were stocked. Results showed higher fecundity, egg/day, egg/day/m³, egg diameter and weight and weight of egg clutch with 10 days resting period (Table 6). One way ANOVA showed significant difference

between variances of fecundity, egg diameter and weight. Means of egg diameter and weight were significantly higher in 10 days resting period than other treatments, by HSD Tukey test ($p<0.05$). Means of egg weight were also significantly higher in 10 days resting period than other treatments, by LSD test ($p<0.05$).

Table 6: Spawning parameters of *O. niloticus* in different resting periods.

Resting period (day)	0	10	15
Mean fecundity±SE	422.4±46.9	634.8±88.5	521.4±50.7
Breeder/day	0.29	0.37	0.4
Egg/day	121.5	234.8	207.1
Egg/day/m ³	101.25	195.7	172.6
Mean egg diameter±SE (mm)	2.78±0.01	2.83±0.03 ^{*H} • ^L	2.76±0.02
Mean egg weight±SE (g)	0.0069±0.0002	0.0073±0.0003 ^{*H}	0.0066±0.0002
Mean egg clutch weight±SE (g)	2.99±0.32	4.97±0.74	3.68±0.43

(^{*H}) shows significantly difference of means of the parameter between the treatment, by HSD Tukey test ($p<0.05$), and (•^L) by LSD test ($p<0.05$).

Water salinity experiment performed with 4 different water salinities as 12±0.5, 8±0.5, 4±0.5 and 0±0.5 ppt, 5 fish/m³ with sex ratio 1:1 were stocked. As the results showed, fecundity and the weight of egg clutch were higher in breeders stocked in 8ppt water salinity. More breeders/day and egg/day were obtained in fresh water. Egg diameter and weight were higher in 12 ppt water

salinity (Table 7). Means of fecundity and egg diameter in 12 ppt water salinity were significantly lower and higher than the other water salinity treatments, respectively, by HSD Tukey test ($p<0.05$). Also, Means of fecundity in 8ppt water salinity and means of egg diameter and weight in 12 ppt water salinity were significantly higher, by LSD test ($p<0.05$). Two tailed Pearson

correlation of water salinity against egg diameter was significantly different ($r=.176$, $p=0.02$). Independent samples t-test showed significantly higher egg diameter in water salinities 4ppt ($t=-.13$,

$p=0.002$) and 12 ppt ($t=-2.95$, $p=0.004$) than fresh water.

Table 7: Spawning parameters of *O. niloticus* in different water salinities.

Water salinity (ppt)	0	4	8	12
Mean fecundity±SE	675±89.8	570±90.1	875±131.5 [•]	586±101 ^{*H}
Breeder/day	0.17	0.15	0.1	0.15
Egg/day	112.5	85.5	87.5	87.8
Egg/day/m ³	93.75	71.25	72.9	73.2
Mean egg diameter±SE (mm)	2.71±0.03	2.84±0.03	2.69±0.05	2.85±0.04 ^{*H•L}
Mean egg weight±SE (g)	0.006±0.0004	0.0071±0.0004	0.0058±0.0003	0.0073±0.0007 ^{•L}
Mean egg clutch weight±SE (g)	4.23±0.5	3.93±0.77	4.51±1	3.92±0.9

(*^H) shows significantly difference of means of the parameter between the treatment, by HSD Tukey test ($p<0.05$), and (•^L) by LSD test ($p<0.05$).

Discussion

Although tilapia breeding is not a complex operation, the production of a large number of quality juveniles requires proper management resulted in good productivity. Spawning performance of Nile tilapia depends on many different factors, especially environmental factors, nutrition, stocking density, age and size of the spawners. Efficiency of the hatchery is affected by the factors and would increase if optimum levels of the factors are used. Nevertheless, the aims of the hatchery are the basis for the management and determining the program. Realization of the potential of tilapia as a candidate species, because of its benefits over others, identification of shortage of quality fry as the main constraint of its expansion and continuous research carried out to find the solutions served as foundation for developing a practical technology

package, for the transfer of knowledge and technology (Bhujel, 2011).

Total length and weight of the smallest Nile tilapia brooder indicates female tilapias with more than 60g weight may spawn. These samples are about 5.5 months old. Nile tilapia females have been reported to spawn at 20g (Popma and Masser, 1999) up to 30-50g and 2-4 months under culture conditions (de Graaf *et al.*, 1999; De Silva and Radampola, 1990; de Graaf, 2004). In nature, Nile tilapia has been reported first sexually mature at 8-16cm and 10-12 months age (Morales, 1991). In Lake Victoria, Njiru *et al.*, (2006) found tilapias first spawning at 22.7 cm. Under culture conditions, tilapia maturation occurs sooner than in the wild and more eggs are produced as a homeostatic response to the environment (Ahmed *et al.*, 2007). Our results showed brooders between 165-495g weight (age 8-20 months) were more frequent spawners.

Larger brooders may be omitted from spawning tanks for better efficiency. Other researchers have shown 6-18 months is the best age range for breeding of female Nile tilapias. Fecundity and egg hatching will decrease in older brooders (Getinet, 2008).

Absolute fecundity of Nile tilapia has been widely documented: 905-7619 eggs in 28-51cm fish (Njiru *et al.*, 2006), 243-847 eggs in tilapias from Zapata lagoon in Mexico (Peña-Mendoza *et al.*, 2005), 2408 ± 70 (Campos-Mendoza, 2004), 305-2000 (Schofield *et al.*, 2011) and <100 up to 3000 eggs (de Graaf *et al.*, 1999) in cultured Nile tilapias. Different relative fecundities have also been reported: 3.12 ± 0.36 (Getinet and Amrit, 2007), 7.2 ± 0.2 (Campos-Mendoza, 2004) and 3.05-7.53 eggs/kg (El-Sayed *et al.*, 2003) in cultured Nile tilapias. Our results in brackish water in Iran were at the lower middle part of the ranges reported by other researchers: 853 ± 25 eggs per spawner and 2.77 ± 0.13 eggs/g. Correlation between fecundity and age of the brooder tilapia is higher than with its weight (Coward and Bromage, 2000). Line regression of fecundity with body weight (Duponchellea *et al.*, 2000), correlation between fecundity and age, total length and weight (Babiker and Ibrahim, 1979) especially in heavier females (Schofield *et al.*, 2011; Peña-Mendoza *et al.*, 2005) has also been reported. However, increasing total length and weight may sometimes lead to lower fecundity (Getinet, 2008; El-Bab *et al.*, 2011). Egg diameter was also related to total length and weight of the brooders ($p < 0.0005$).

Positive correlation of brooder size and wet egg weight has been recorded by other researchers (Duponchellea *et al.*, 2000). Selection of larger brooders for spawning may result in higher quality eggs. Researchers have reported different diameters of Nile tilapia eggs from 1 to 3.7mm (Fryer and Iles, 1972; Babiker and Ibrahim, 1979; de Graff *et al.*, 1999; Coward and Bromage, 2000; Gómez-Márquez *et al.*, 2003). Egg diameters of tilapias obtained in the present study with mean of 2.58 ± 0.009 mm are mid-range.

As results of the sex ratios experiment showed, the highest fecundity, egg/day, egg/ breeder, egg diameter and minimum intervals of spawning were obtained in sex ratio 1: 1. The higher egg/day and better quality eggs make increased performance of the fry production, so it seems that sex ratio 1: 1 the better sex ratio than the other studied sex ratios. However, reproductive parameters in sex ratios 1: 1, 1: 4 and 1: 7 were similar without significant differences and would be used based on the hatchery aims and management. Different investigations on the sex ratio stocking of the Nile tilapia have showed different results. The sex ratio 1: 1 is suggested for mating of tilapia in hatcheries (Little, 1989; Delong *et al.*, 2009) and more fry per female but not continuous (Ibara *et al.*, 2000). The optimum sex ratio may also be affected by the broodstock density. Broussard *et al.* (1983) found that increasing broodstock density, at M: F sex ratio of 1:3, had a negative effect on fry production of Nile tilapia reared in

ponds. The authors attributed that effect to increasing competition between territorial males and/or constraints imposed by feed availability. Fessehaye (2006) found that reproduction success of *O. niloticus* with sex ratio of 1:1 declined compared to sex ratio 1:3, in hapa. A sex ratio of 1:3 (M:F) is commonly used by tilapia hatchery operators. However, lower ratios typically result in higher seed production, probably due to the availability of more mature males per female. Most commercial hatcheries in Thailand that have adopted the use of hapas or net cages in ponds maintain a 1:1 sex ratio to ensure high spawning and fertilization rates. They stock 6 fish/m² of hapa suspended in inorganically fertilized ponds and provide supplementary feeding. The density can be doubled in tanks when complete feeds are provided (Bhujel, 2000). In 2000-1000m pools, sex ratio 2:1 to 8:1 (F:M) is used (Huy *et al.*, 2003). Fry production decreases with ratios greater than 4:1 (F:M). Rana (1988) found that when the sex ratio was changed from 4:1 to 3:1 (F:M) the spawning interval was reduced from 35-49 days to only 28-40 days. Even though mating can occur and fry can be produced from ratios of one or two females per male, commercial hatcheries usually use four or five females per male (DeLong *et al.*, 2009). Planning in a hatchery depends on the objectives of the workshop. It seems that no single sex ratio can be adopted for the optimum reproduction efficiency of tilapia. The hatchery manager would decide the most

appropriate sex ratio based on the tilapia species, size and age, culture system and hatchery program.

Results of stocking density experiment showed the density 5 fish/m³ was more appropriate. Tahoun *et al.* (2008) studied fry production of broodstock with three different densities 4, 8 and 12 fish/ m. The best growth performance and feed utilization were found in fry group spawned by broodstock, held at the 4 fish/ m² stocking density. Ridha and Cruz (1999) studied the effect of different stocking densities on the seed production of Nile tilapia, *Oreochromis niloticus* (L.), under intensive recycling hatchery system conditions. They showed that breeders stocked at 4 fish m⁻² had significantly higher mean values for total seed production ($p < 0.05$), seed kg⁻¹ female day⁻¹, seed female⁻¹ day⁻¹, seed m⁻² day⁻¹ and spawning synchrony, than at 8 and 12 fish m⁻² broodstock densities. The mean percentage of seeds in the yolk-sac and swim-up fry stages was highest at 4 fish m⁻² broodstock density. Several studies have shown that reproduction in tilapias can be inhibited under high stocking densities (Turner *et al.*, 1989; Coward *et al.*, 1998; Tahoun *et al.*, 2008). One of the physiological mechanisms associated with these shifts in behavior is the suppression of serum sex steroid levels in the females; levels rise rapidly when fish are transferred to less crowded conditions, usually concurrent with a renewal of spawning activity (Coward *et al.*, 1998). Stocking densities over 10 kg/m³ have resulted in no successful spawning (Zimmerman *et*

al., 2000).

Higher breeder/day, egg/day, egg diameter and weight of egg clutch and lower spawning intervals were obtained in 12:12 photoperiod comparing 12:12, 6:18 and 18:6 (L:D) photoperiods. Different researchers showed the effects of photoperiod on *O. niloticus* reproduction. El-Sayed and Kawannah (2007) found the best growth rate and FCR at 18L:6D, followed by 24L:0D, 12L:12D and 6L:18D, respectively. The number of eggs per female, number of eggs per spawn and number of spawning per female were all significantly higher in the 12L: 12D treatment than in all other photoperiod cycles. Interspawning intervals and days elapsed per spawn were also shorter in the 12L: 12D treatment. The 18L: 6D and 6L: 18D photoperiods produced the lowest spawning performance. They concluded that a 12L:12D photoperiod regime should be adopted for maximum fecundity, seed production and spawning frequencies of Nile tilapia broodstock reared in intensive, recirculating systems. If maximum reproduction is desired, a near-natural day length photoperiod should be used. Campos Mendoza *et al.* (2003 and 2004) studied spawning of Nile tilapia under four different photoperiods: 6L: 18D, 12L:12D, 18L:6D and continuous illumination 24L:0D. Significantly larger eggs ($p \leq 0.05$) were produced under normal daylength 12L:12D compared to other treatment groups. Fish reared under 18L:6D exhibited significantly higher ($p \leq 0.05$) total fecundity (2408 ± 70 eggs spawn⁻¹) and

relative fecundity (7.2 ± 0.2 eggs g⁻¹ body weight) concomitant with a significant reduction in inter-spawn-interval (ISI, 15 ± 1 days) in comparison with the rest of the trials. Their investigation shows that long daylength (18L:6D) helps improve some important reproductive traits in Nile tilapia. Seed production has been increased by increasing photoperiod and notable drops in seed production have been recorded when photoperiod was below 12 hrs. of light (Baroiller *et al.*, 1997).

Comparing 10-days, 15-days and without rest period *O. niloticus* breeders in the present study, showed 10-days rest period was more appropriate due to higher levels of fecundity, egg/day, the weight of the egg mass, the weight and diameter of the eggs. Other researchers also represented effects of rest periods of the Nile tilapia broodstock a favorable influence on the efficiency of replication. If fish were to reproduce every two weeks for a long period of time, production would drop off as the females became exhausted. Resting of the broodstock is a common practice to prevent this. Fish are allowed to remain in the brooding tanks until production begins to drop in about three months. They are then moved to a conditioning tank to rest for a period of about six months. To maintain a continuous production of fry three sets of broodstock must be maintained (Rosati *et al.*, 1997). Production of eggs per unit area of hapas were significantly higher in females exchanged every 7 days, 64 eggs/m²/day or at each harvest 3.5 days, 55 eggs/m²/day, than for fish remaining

in the spawning hapas throughout the trial 0 day, 33 eggs/m²/day (Little *et al.*, 2000). Popma and Lovshin (1995) showed harvesting every 2 to 3 weeks without broodstock replacement, monthly production is 1 to 2 fry/gr of breed female. Fry harvest per spawning cage may be double if broodfish are replaced each cycle, but this practice is considerably more labor-intensive.

Results of water salinity experiment in our study showed fecundity and the weight of egg clutch were higher in breeders stocked in 8 ppt water salinity. More breeders/day and egg/day were obtained in fresh water. Egg diameter and weight were higher in 12 ppt water salinity. According to various surveys, water salinity has different effects on different parameters of Nile tilapia reproduction. Schofield *et al.* (2011) showed batch fecundity did not differ among 0, 10, 20, and 30 ppt treatments. However, the number of eggs produced declined significantly at salinities of 40 ppt and above. Similarly, the production of vitellogenic oocytes was significantly reduced above 30 ppt. Watanabe *et al.* (1984) suggested hatching of the larger brooders of Nile tilapia in 5 ppt water salinity higher than fresh water, however, hatching success generally declined in 10 ppt and 15ppt salinities. The inhibitory effect of high salinity on reproduction was evidenced by considerably lowered hatching successes at 10 ppt and 15 ppt, successful hatching was not achieved in full seawater. *O. niloticus* most cultured in freshwater, however saline tolerant species that grows well at salinities up to

15ppt. *O. niloticus* can reproduce in salinities of 10 to 15 ppt. *O. niloticus* produce fry equally well in freshwater and 5 ppt salinity but fry numbers begin to decline at 10 ppt salinity. Ideally, tilapia hatcheries should be located in freshwater or in water with less than 5 ppt salinity and the fry transferred to higher salinities for further growth (Popma and Lovshin, 1995).

Mean hatching successes were similar for eggs spawned by yearling females in freshwater, 10 ppt and 15 ppt, respectively. Extremely poor hatching success was obtained with eggs spawned in full seawater. Mean hatching success was considerably higher for eggs spawned at 5 ppt and compared with that obtained with eggs spawned by older females in freshwater (Watanabe *et al.*, 1984). Higher fecundity and more egg clutch weight in 8ppt and better egg quality parameters in 12 ppt water salinity in the present study suggests favorite breeding of spawners in brackish water especially 8 ppt water salinity. Also, Watanabe *et al.* (1984) showed fry salinity tolerance progressively increased with increasing salinity of spawning, hatching, or acclimatization. However, at equivalent salinity, early exposure (spawning) produced progeny of comparatively higher salinity tolerance than those spawned in freshwater and hatched at elevated salinity. Similarly, at equivalent salinity, progeny spawned in freshwater but hatched at elevated salinity exhibited higher salinity tolerance than those spawned and hatched in freshwater, then acclimatized to an elevated salinity.

Furthermore, using brackish water for aquaculture purposes would be preferred due to the limitation of fresh water supply and its cost.

Bringing the eggs out of the mouth of the brooders, high density of brooders before reproduction and replacing brooders for a resting period may cause more synchronized spawning of females (Little, 1989, Lovshin and Ibrahim, 1989; Bhujel, 2000). Spawning frequency in tilapias is seriously influenced by environmental factors. Also, younger Nile tilapias often have shorter reproduction cycles. Low protein nutrition regimes cause longer reproduction cycles (Srisakultiew, 1993; Coward and Bromage, 2000; Herbst, 2002; Peña-Mendoza *et al.*, 2005).

References

- Ahmed, A.A., Abdallaa, M.S. and George, T.T., 2007.** Egg Enumeration, incubation, hatching and development of the "Miracle Fish", *Oreochromis niloticus*, in the Sudan. *AAC Special Publication*, 12, 60-64.
- Babiker, M. M. and Ibrahim, H., 1979.** Studies on the biology of reproduction in the cichlid *Tilapia nilotica* (L.): gonadal maturation and fecundity. *Journal of Fish Biology*, 14, 437-448.
- Baroiller, J. F., Desprez, D., Carteret, Y., Tacon, P., Borel, F., Hoareau, M.C., Melard, C. and Jalabert, B., 1997.** Influence of environmental and social factors on the reproductive efficiency in three tilapia species, *Oreochromis niloticus*, *O. aureus*, and the red tilapia (Red Florida strain). In: *Proceedings from the Fourth International Symposium on Tilapia in Aquaculture, Orlando Florida, November 9-12*, ed. K. Fitzsimmons. 238-252. Northeast Aquacultural Engineering Service, Ithaca, New York.
- Bhujel, R.C., 2011.** A Guidebook for the Culture of Mouth brooding Tilapias (*Oreochromis* sp.) in Zambia. *Aquaculture and Aquatic Resources Management (AARM)*, Asian Institute of Technology (AIT), Bangkok, Thailand.
- Bhujel, R.C., 2000.** Advances in tilapia broodstock management. *Global Aquaculture Advocate*, 3(5), 19-22.
- Broussard, M.C., Reyes, R. and Raguindin, F., 1983.** Evaluation of hatchery management schemes for large scale production of *Oreochromis niloticus* fingerlings in Central Luzon, Philippines, 414-424. In L. Fishelson and Z. Yaron (comps.) *International Symposium on Tilapia in Aquaculture*, Nazareth, Israel, 8 - 13 May 1983, Tel Aviv University, Tel Aviv, Israel.
- Campos-Mendoza, A., Bromage, N. and McAndrew, B.J., 2003.** The effect of photoperiod on the reproductive performance of the Nile tilapia, *Oreochromis niloticus*. *Fish Physiology and Biochemistry*, 28(1-4), 503-504. <https://doi.org/10.1023/B:FISH.0000030641.95659.be>
- Campos-Mendoza, A., McAndrew, B.J., Coward, K. and Bromage, N., 2004.** Reproductive response of Nile

- tilapia (*Oreochromis niloticus*) to photoperiodic manipulation; effects on spawning periodicity, fecundity and egg size. *Aquaculture*, 231(1-4), 299-314.
<https://doi.org/10.1016/j.aquaculture.2003.10.023>
- Coward, K., Bromage, N.R. and Little, D.C., 1998.** Inhibition of spawning and associated suppression of sex steroid levels during confinement in the substrate spawning *Tilapia zilli*. *Journal of Fish Biology*, 52, 152-165.
<https://doi.org/10.1111/j.1095-8649.1998.tb01560.x>
- Coward, K. and Bromage, N.R., 2000.** Reproductive physiology of female tilapia broodstock. *Reviews in Fish Biology and Fisheries*, 10, 1-25.
<https://doi.org/10.1023/A:1008942318272>
- de Graaf, G.J., Galemoni, F. and Huisman, E.A., 1999.** Reproductive biology of pond reared Nile tilapia, *Oreochromis niloticus* L. *Aquaculture Research*, 30, 25-33.
- de Graaf, G.J., 2004.** Optimization of the pond rearing of *Nile tilapia* (*Oreochromis niloticus niloticus* L.). The impact of stunting processes and recruitment control. PHD Thesis, Wageningen University, Netherlands, 160P.
- De Silva, S.S. and Radampola, K., 1990.** Effect of dietary protein on the reproductive performance of *Oreochromis niloticus*. In: Hirano, Hanyu _Eds., *The Second Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines*. 991 P.
- DeLong, D.P., Losordo, T.M. and Rakocy, J.E., 2009.** *Tank Culture of Tilapia*, SRAC Publication, No. 282.
- Duponchellea, F., Cecchib, P., Corbinb, D., Nuñez J. and Legendre, M., 2000.** Variations in fecundity and egg size of female Nile tilapia, *Oreochromis niloticus*, from man-made lakes of Cote d'Ivoire. *Environmental Biology of Fishes*, 57, 155-170.
- El-Bab, A.F.F., M.E. Farag, A.A. Ramadan and Hassan, A.S., 2011.** Effect of temperature and female weight on reproductive performance of two Nile tilapia (*Oreochromis niloticus*) populations. *Egyptian Journal of Aquatic Biology and Fisheries*, 15(2), 179–193.
- El-Sayed, A.M., Mansour, C.R. and Ezzat, A.A., 2003.** Effects of dietary protein levels on spawning performance of Nile tilapia (*Oreochromis niloticus*) broodstock reared at different water salinities. *Aquaculture*, 220, 619-632.
- El-Sayed, A.M., 2006.** *Tilapia culture*. CABI Pub. 277P.
<https://doi.org/10.1079/9780851990149.0000>
- El-Sayed, A.F. and Kawanna, M., 2007.** Effects of photoperiod on growth and spawning efficiency of Nile tilapia (*Oreochromis niloticus* L.) broodstock in a recycling system. *Aquaculture Research*, 38(12), 1242-1247.
<https://doi.org/10.1111/j.1365-2109.2007.01690.x>
- Fessehaye, Y., 2006.** Natural mating in Nile tilapia (*Oreochromis niloticus*

- L.) Implications for reproductive success, inbreeding and cannibalism. PhD thesis, 149P. Wageningen University, Netherlands.
- Fryer, G. and Iles, T.D., 1972.** *The cichlid fishes of the great lakes of Africa: Their biology and evolution*, 641. Edinburgh, UK: Oliver and Boyd.
- Getinet, G.T. and Amrit, N.B., 2007.** Effects of feeding, stocking density and water-flow rate on fecundity, spawning frequency and egg quality of Nile tilapia, *Oreochromis niloticus* (L.). *Aquaculture*, 272(1-4), 380-388.
- Getinet, G.T., 2008.** Effects of Maternal Age on Fecundity, Spawning Interval, and Egg Quality of Nile tilapia, *Oreochromis niloticus* (L.). *Journal Of the World Aquaculture Society*, 39(5), 671-677.
- Gómez-Márquez, J.L., Pe-Mendoza, B., Salgado-Ugarte, I.H. and Guzmán-Arroyo, M., 2003.** Reproductive aspects of *Oreochromis niloticus* (Perciformes: Cichlidae) at Coatetelco lake, Morelos, Mexico. *Revista de Biología Tropical*, 51, 221-228.
- Herbst, E.C., 2002.** Induction of tetraploidy in zebrafish *danio rerio* and Nile tilapia *Oreochromis niloticus*. M.Sc Thesis, University of North Carolina at Charlotte, USA, 127P.
- Huy, H.P.V., MacNiven, A. Tu, N.V. Bhujel, R.C. and Little, D.C., 2003.** Tilapia seed production in Ho Chi Minh City, Southern Vietnam. *Aquaculture Asia*, VIII(4), 23-25.
- Ibara R., Tassinari, J. and Fraser, J., 2000.** Tilapia Aquaculture in Urban "Brownfields": A Demonstration Project, the Massachusetts Aquaculture Grants Program, Massachusetts Department of Food and Agriculture, 49P.
- Little, D.C., 1989.** An evaluation of strategies for production of Nile tilapia *Oreochromis niloticus* fry suitable for hormonal treatment. PhD thesis, Institute of Aquaculture, Univ. of Stirling, Stirling, Scotland, UK.
- Little, D.C., Macintosh, D.J. and Edwards, P., 1993.** Improving spawning synchrony in the Nile tilapia, *Oreochromis niloticus* (L.). *Aquaculture and Fisheries Management*, 24, 399-405. <https://doi.org/10.1111/j.1365-2109.1993.tb00563.x>
- Little, D.C., Coward, K. Bhujel, R.C. Pham, T.A. and Bromage N.R., 2000.** Effect of broodfish exchange strategy on the spawning performance and sex steroid hormone levels of *Oreochromis niloticus* broodfish in hapas. *Aquaculture*, 186, 77-88. [http://dx.doi.org/10.1016/S0044-8486\(99\)00368-3](http://dx.doi.org/10.1016/S0044-8486(99)00368-3)
- Lovshin, L.L. and Ibrahim, H.H., 1989.** Effects of broodstock exchange on *Oreochromis niloticus* egg and fry production in net enclosures. In: Pullin, R.S.V., Bhukaswan, T., Tonguthai, K., Maclean, J.L. _Eds., *The Second International Symposium on Tilapias in Aquaculture*, ICLARM, 231-236.

- Mashaii, N., 2012.** Optimization of breeding (salinity, light regime, brood density and sex ratio) of cultured tilapia under brackish water of Bafgh, Iran. Final report of research, Iranian Fisheries Science Research Institute, N 41274.
- Mashaii, N., 2016.** An investigation on breeding and fry production of cultured tilapia in brackish water of Bafq, Iran. Final report of research, Iranian Fisheries Science Research Institute, N 49231.
- Morales, D.A., 1991.** *La Tilapia en México. Biología, Cultivo y Pesquerías.* AG, México, D.F. 190P.
- Njiru, M., Ojuok, J.E., Okeyo-Owuor, J.B., Muchiri, M., Ntiba, M.J. and Cowx, I.G., 2006.** Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. *African Journal of Ecology*, 44, 30-37.
- Peña-Mendoza, B., Gómez-Márquez, J.L., Salgado-Ugarte, I.H. and Ramírez-Noguera, D., 2005.** Reproductive biology of *Oreochromis niloticus* (Perciformes: Cichlidae) at Emiliano Zapata dam, Morelos, Mexico. *Revista de Biología Tropical (International Journal of Tropical Biology)*, 53(3-4), 515-522.
- Popma, T. Masser, M., 1999.** Tilapia Life History and Biology, 2. SRAC Pub. No. 283.
- Popma, T.J. and Lovshin, L.L., 1995.** Worldwide prospects for commercial production of tilapia. 42P. International Center for Aquaculture and Aquatic Environments, Department of Fisheries and Allied Aquacultures, Auburn University, Alabama.
- Rajabipour, F., 2013.** An investigation on feasibility of introduction of tilapia to aquaculture industry of inland brackishwaters at desert areas of Iran. Final report of the project, 96P. National Research center of Saline Water Aquatics, Iranian Fisheries Research Organization Pub. Agricultural Research, Education and Extension Organization (AREEO), In Persian.
- Rana, K., 1988.** Reproductive biology and the hatchery rearing of tilapia eggs and fry. (Pp343- 406), ed. J. F. Muir, and R. J. Roberts. *Recent Advances in Aquaculture* V3. London: Croom Helm.
- Ridha, M.T. and Cruz, E.M., 1999.** Effect of different broodstock densities on the reproductive performance of Nile tilapia, *Oreochromis niloticus* (L.), in a recycling system. *Aquaculture Research*, 30(3), 203-210. <https://doi.org/10.1046/j.1365-2109.1999.00311.x>
- Rosati, R., Foley, P., O'Rourke, P.D. and Tudor, K., 1997.** Operation of a Prototype Commercial-Scale Hatchery System for *Oreochromis niloticus*, ed. K. Fitzsimmons. Tilapia Aquaculture: *Proceedings from the Fourth International Symposium on Tilapia in Aquaculture*. V1. 319-329. Ithaca, NY: Northeast Regional Agriculture Engineering Service.
- Schofield, P.J., Peterson, M.S., Lowe, M.R., Brown-Peterson, N.J. and**

- Slack, W.T., 2011.** Survival, growth and reproduction of non-indigenous Nile tilapia, *Oreochromis niloticus* (Linnaeus 1758). I. Physiological capabilities in various temperatures and salinities. *Marine and Freshwater Research*, 62, 1-11.
- Srisakultiew, P., 1993.** Studies on the reproductive biology of *Oreochromis niloticus* (L.). PhD thesis, Institute of Aquaculture, Univ. Stirling, UK.
- Tahoun, A.M., Ibrahim, M.A.R., Hammouda, Y.F., Eid, M. S., Zaki El-Din, M.M.A. and Magouz, F.I., 2008.** Broodstock age, stocking density and fecundity of Nile tilapia, *Oreochromis niloticus* (L.) In hapa based hatchery system. *The 8th International Symposium on Tilapia in Aquaculture*, October 12-14, 2008, Cairo, Egypt.
- Turner, G.F., Phirl, L.M. and Cawthraw, S., 1989.** Partner attack inhibition in the sexually monomorphic biparental cichlid *Tilapia mariae*. *Behaviour*, 109, 1-19.
- Watanabe, W.O., Kuo, C.M. and Huang, M.C., 1984.** Experimental rearing of Nile tilapia fry (*Oreochromis niloticus*) for Salt water culture. *ICLARM Technical Reports*, 14, 28P.
- Zimmerman, K., Brown, R., Magdy, A. and Ibara, R.M., 2000.** A brief review of tilapia reproduction and preliminary fry production experiments with hybrid tilapia (*Oreochromis niloticus* x *O. aureus*). A Subsection of the Project Report: AGRAQUA-298 "Tilapia Aquaculture in Urban "Brownfields": A Demonstration Project", 1998 Prepared for The Massachusetts Aquaculture Grants Program Massachusetts Department of Food and Agriculture.