Macrothink Institute™

Aquatic Science and Technology
ISSN 2168-9148
2019, Vol. 7, No. 1

Some Spawning Performance Parameters of Cultured Nile Tilapia *Oreochromis niloticus*, under Brackish Water

Nassrin Mashaii[1] (Corresponding author), Farhad Rajabipour[2], Mohammad Jafari[3], Mohamad Mohammadi[4], Habib Sarsangi[5], Homayun Hossein-Zadeh[6] & Abbas Matinfar[7]

[1,2,3,4,5] National Research center of Saline Water Aquatics, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Bafq, Yazd, Iran

[6,7]Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran

Correspondence: Nassrin Mashaii. E-mail: nassrinmashaii@yahoo.com

Received: Sep. 17, 2018 Accepted: Sep. 26, 2018 Published: Oct. 21, 2018

doi:10.5296/ast.v7i1.13660 URL: https://doi.org/10.5296/ast.v7i1.13660

Abstract

Tilapia is one of the most important cultured fish in the world. However, the gap between seed supplies and farmers' demand is one of the serious limitations for tilapia culturists. Notice about different effective agents on tilapia reproduction might be useful for increasing of production and better management of tilapia hatcheries. In the present study, higher efficiency of tilapia *Oreochromis niloticus* hatchery was considered based on the impact of sex ratio, stocking density, photoperiod, water salinity and replacement period on spawning performance. Sex ratios 1:1, 1:4 and 1:7 (Male: Female), stocking densities 2, 3.5 and 5 fish/m^3, photoperiods 6:18, 12:12 and 18:6 (Light:Dark), water salinities 12, 8, 4 and 0 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/m^3, photoperiod 12:12, 8 ppt water salinity and 10 days replacement had better performance. Sex ratio treatments had similar performance.

Keywords: Nile tilapia, breeding, hatchery, brackish water

1. Introduction

Tilapias are the world's second largest farmed group of fish and their production in the world has sharply increased, especially in recent decades. Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) production consisted more than 70% of total farmed tilapia in the last decade. Tilapia farming is now done in more than 140 countries and its' global production has exceed than 5.6 million tons (Fitzsimmons, 2016; FAO, 2014).

Management improvement of the hatcheries is essential for development of tilapia production. Increased knowledge of the factors regulating broodstock productivity is of great importance to the further development of tilapia culture. Tilapia sexual maturity and spawning performance resulted from different factors especially the total environmental approach, age and weight, stocking density, sex ratio and nutrition (Tahoun et al., 2008; Coward and Bromage, 2000; Popma and Masser, 1999).

In the Nile tilapia living in the nature, environmental factors such as light, temperature rain and pH affecting gonad maturity (El-Naggar et al., 2000). Cultured tilapias mature earlier and produce more eggs than naturally living tilapias. This is an adaptive response to the environmental conditions (Ahmed et al., 2007).

Differences between populations of Nile tilapia breeding reflect the phenotypic plasticity of this species in the face of different environmental situations. In fact, the response of reproductive processes of tilapia to environmental conditions raised the environmental perspective sensitivity to tilapia.

The more tilapia culture is expanded, the more it becomes vital to produce sufficient amounts of seed to meet the increasing demand of tilapia farmers. The current status of tilapia culture in many countries suggests that there is a gap between seed supplies and farmers' demand. 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)].

Nile tilapia *O. niloticus* samples were entered to Iran for research purposes at December 2008 for the first time. Studies about the feasibility of introduction of tilapia to inland aquaculture in Iran were begun in National Research Center of Saline Water Aquatics in Yazd province at the center of Iran (Rajabipour, 2013). Different aspects of reproduction, culture, feeding, monosex production, processing are studied (Bitaraf, 2012; Mashaii et al., 2016; Mohammadi et al., 2014; Morady et al., 2012; Rajabipour, 2013 & 2016; Sarsangi et al., 2012).

Tilapia aquaculture is new in Iran. Also, there are few investigations about reproductive biology of Nile tilapia in brackish water condition. Reproductive of Nile tilapia in brackish water condition in Iran was previously studied. The absolute fecundity, spawning intervals and hatch percents of cultured *O. niloticus* in brackish water were measured (Mashaii et al., 2016). Optimization of the reproductive factors is necessary for increasing the efficiency of tilapia hatchery. In the present study, 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.

2. Materials and Methods

This research was performed in hatchery of National Research Center of Saline Water Aquatics in the vicinity of Bafq city in Yazd province at the center of Iran. Underground brackish water resources are used for aquaculture. A 100 μm disc filter removed particulates from the entrance water before arriving to the hatchery. A central air blower with a continual flow was used for aeration.

Separate experiments conducted to investigate the density, sex ratio, photoperiod, salinity and exchange period of Nile tilapia, *Oreochromis niloticus* spawners during 2012 to 2014. Each experiment lasted for 3 months.

There was a constant flow of water in the fish tanks. The amount of water temperature was maintained 27±0.5 ℃, water salinity was 9.5±0.5 ppt and 2500 lux light (12L:12D) during the experiments. Breeders with 120-170 g mean weight were stocked in 2 m^3 tanks in the experiments. To achieve the desired volume of water and the density storage in tanks, the height of drain pipe was set. Fish were fed using 40% crude protein pellets twice a day. Elastomere tags were used for recognition of female fish. Breeders were tagged unilateral or bilateral in pectoral, abdominal and caudal positions.

Total body length and weight of the spawned females were recorded after bringing out the eggs. Eggs were collected two times a week. Total eggs of each spawner in each egg laying were counted, also weight and the diameters of about 35 eggs from each egg clutch were measured. Absolute fecundity, the number of spawner/day, egg/day, egg/spawner, egg/day/m^3, mean length, weight and wet weight of eggs and mean of spawning intervals were obtained.

For sex ratio experiment, breeders were stocked as 1:1, 1:4 and 1:7 (Male: Female). Stocking density of fish was 5 fish/m^3, 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/m^3 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 (Light: Dark).

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/m^3 and sex ratio 1:1.

Statistics: 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 ($p<0.05$). Pearsons' 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 ($p<0.05$). (McDonald, 2014).

3. Results

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 1).

Table 1. Spawning parameters of *O. niloticus* in different sex ratios 1:1, 1:4. 1:7 (M: F).

Sex ratio (M: F)	1:1	1:4	1:7
Mean fecundity ±SE	712±49.4	613±45.5	641±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 intervals ±SE (day)	20.2±6	29.2±11.5	27.6±10.9
Mean egg diameter ±SE (mm)	2.97±0.03	2.93±0.03	2.89±0.02

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 ($p>0.05$).

As the results of the stocking density experiment for 2, 3.5 and 5 fish/m^3 with sex ratio 1:3 (Male: Female) showed, fecundity and egg/day/m^3 were higher in stocking density 2/m^3. However, breeder/day, length, weight and wet weight of the eggs were higher in 5 fish/m^3 along with shorter spawning intervals (Table 2).

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/m^3 breeders were significantly higher than the other stocking densities of the breeders, by HSD Tukey test ($p<0.05$).

Aquatic Science and Technology
ISSN 2168-9148
2019, Vol. 7, No. 1

Table 2. Spawning parameters of *O. niloticus* in different stocking densities 2, 3.5, 5 fish/m^3., sex ratio 1:3.

Density (fish/m^3), sex ratio 1:3	2	3.5	5
Mean fecundity ±SE	846.4±80.9	620±75.4	593.7±61.9
breeder/day	0.38	0.49	0.55
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 ($p<0.05$).

Results of the stocking density experiment for 2, 3.5 and 5 fish/m^3 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/m^3. However, breeder/day, length, weight and wet weight of the eggs were higher in 5 breeders/m^3 along with shorter spawning intervals (Table 3).

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/m^3 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 ($r=.149$, $p=0.002$) and 1:1 ($r=.166$, $p=0.004$).

Results of 12:12, 6:18 and 18:6 (L:D) photoperiod experiment for 5 fish/m^3 with sex ratio 1:1 showed more fecundity in 18:6 (L:D) photoperiod. Higher breeder/day, egg/day, egg/day/m^3, egg diameter and weight of egg clutch and lower spawning intervals were obtained in 12:12 photoperiod (Table 4).

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 3. Spawning parameters of *O. niloticus* in different stocking densities 2, 3.5, 5 fish/m^3., sex ratio 1:1.

Density (fish/m^3), sex ratio 1:1	2	3.5	5
Mean fecundity ±SE	507 ±57.4	636 ±65.6	343 ±39.5
Breeder/day	0.2	0.23	0.51
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).

Table 4. Spawning parameters of *O. niloticus* in different photoperiods 6:18, 18:6, 12: 12 (L: D).

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/m^3 with sex ratio 1:1 were stocked. Results showed higher fecundity, egg/day, egg/day/m^3, egg diameter and weight and weight of egg clutch with 10 days resting period (Table 5).

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 ($p<0.05$).

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/m^3 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 6).

Table 5. Spawning parameters of *O. niloticus* in different resting periods 0, 10, 15 days.

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$*^{H\,\bullet L}$	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 ($^{\bullet L}$) by LSD test ($p<0.05$).

Table 6. Spawning parameters of *O. niloticus* in different water salinities 0, 4, 8, 12 ppt.

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 ($p<0.05$).

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 ($t=-3.13$, $p=0.002$) and 12 ppt ($t=-2.95$, $p=0.004$) than fresh water.

4. Discussion

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 has showed different results. The sex ratio 1: 1 is suggested for mating of tilapia in hatcheries (Delong et al., 2009, Little, 1989) 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/m^2 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.

In the present study, the results of stocking density experiment showed the density 5 fish/m^3 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/ m^2 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 (Tahoun et al., 2008; Turner et al., 1989; Coward et al., 1998). 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/m^3 have resulted in no successful spawning (Zimmerman et al., 2000). Besides, at high densities, there is a competition for space which increases social interaction and in turn, causes social stress and possibly thereby affecting reproductive efficiency (Tahoun et al., 2008).

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 ($P\leq0.05$) 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/m^2/day or at each harvest 3.5 days, 55 eggs/m^2/day, than for fish remaining in the spawning hapas throughout the trial 0 day, 33 eggs/m^2/day (Little et al., 2000). Popma & 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 pawned 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.

Present study suggests optimums of the stocking density, sex ratio and replacement period of the breeders, photoperiod and water salinity. 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.

References

Ahmed, A. A., Abdallaa, M. S., & George, T. T. (2007). Egg Enumeration, incubation, hatching and development of the "Miracle Fish", *Oreochromisn niloticus*, in the Sudan. *AAC Special Publication, 12*, 60-64.

Baroiller, J. F., Desprez, D., Carteret, Y., Tacon, P., Borel, F., Hoareau, M. C., Melard, C., & 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. (2000). Advances in tilapia broodstock management. *Global Aquaculture Advocate*, *3*(5). 19-22.

Bitaraf, A. (2012). An investigation on all male production of Nile tilapia (*Oreochromis niloticus*) under the condition of brackish water in Bafgh. Final report of the project, 46P. Brackish Inland water fisheries Research Center, Iranian Fisheries Science Research Institute.

Broussard, M. C., Reyes, R., & Raguindin, F. (1983). Evaluation of hatchery management schemes for large scale production of *Oreochmmis 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., & 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., & 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., (2000). Reproductive physiology of female tilapia broodstock. *Reviews in Fish Biology and Fisheries, 10*, 1-25. https://doi.org/10.1023/A:1008942318272

Coward, K., Bromage, N. R., & 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

DeLong, D. P., Losordo, T. M., & Rakocy, J. E. (2009). *Tank Culture of Tilapia*, SRAC Publication, No. 282.

El-Naggar, G. O., El-Nady, M. A., Kamar, M. G., & Al-Kobaby, A. I. (2000). Effect of photoperiod, dietary protein and temperature on reproduction in Nile tilapia (*Oreochromis niloticus*). In: *Proceedings from the Fifth International Symposium on Tilapia Aquaculture*, ed. K. Fitzsimmons, & J. Caravalho Filho Rio de Janeiro, Brazil. 352-358.

El-Sayed, A. M. (2006). *Tilapia culture*. CABI Pub. 277P. https://doi.org/10.1079/9780851990149.0000

El-Sayed, A. F., & 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

F.A.O. (2014). The state of world fisheries and aquaculture opportunities and challenges. Rome, 2014.

Fessehaye, Y. (2006). Natural mating in Nile tilapia (*Oreochromis niloticus* L.) Implications for reproductive success, inbreeding and cannibalism. PhD thesis, 149P. Wageningen University, Netherlands.

Fitzsimmons, K. (2016). Supply and demand in global tilapia markets 2015. *World Aquaculture Society*, Feb. 2016, Las Vegas, USA.

Fryer, G., & Iles, T. D. (1972). *The cichlid fishes of the great lakes of Africa: Their biology and evolution*, 641. Edinburgh, UK: Oliver and Boyd.

Guerrero, R. D. III. (1982). Control of tilapia reproduction. (Pp 309-316), ed. R. S. V. Pullin, and R, H. Lowe- McConnell. In: The Biology and Culture of Tilapias. *ICLARM Conference Proceedings* 7, P. 432. International Center for Living Aquatic Resources Management, Manila Philippines.

Huy, H. P. V., MacNiven, A. Tu, N. V. Bhujel, R. C., & Little. D. C. (2003). Tilapia seed production in Ho Chi Minh City, Southern Vietnam. *Aquaculture Asia*, *VIII*(4), 23-25.

Ibara R., Tassinari, J., & Fraser. J. (1998). 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., & 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., & 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

Mashaii, N., Rajabipour, F., Mohammadi, M., Sarsangi, H., Bitaraf, A., Hossein-Zadeh, H., & Sharif-Rohani, M. (2016). Reproduction of Nile tilapia, *Oreochromis niloticus* in brackish water. *Journal of Applied Aquaculture*, *27*(4), 1–8. https://doi.org/10.1080/10454438.2015.1104943

McDonald, J. H. (2014). *Handbook of Biological Statistics*. (3rd ed.). Maryland: Sparky House Publishing. 305P.

Mohammadi, M., Sarsangi, H., Haghighi, D., Webster, C., Rajabipour, F., Mashaii, N., Bitaraf, A., & Hafeziyeh, M. (2014). Optimization of dietary protein in all male Nile tilapia (*Oreochromis niloticus*) reared in inland saline water. *Animal Nutrition and Feed Technology, 14*(1), 91-99. URL: http://www.anft.org

Morady, Y., Mashaeii, N., Karami, B., & Zare-Ghasti, Gh. (2012). Investigation on proximate composition, fatty acid profile and sensory evaluation of Nile (*Oreochromis niloticus)* and hybrid red Tilapia fillet farmed in brackish ground water of Bafgh, Yzad. *Iranian Scientific Fisheries Journal, 21*(2), 125-132.

Popma, T. J., & 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.

Popma, T., & Masser, M. (1999). Tilapia Life History and Biology, 2. SRAC Pub. No. 283.

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.

Rajabipour, F. (2016). Pathogen monitoring in indoor systems of tilapia aquaculture in Bafq, Iran. Final report of the project, 69P. National Research center of Saline Water Aquatics, Iranian Fisheries Research Organization, Agricultural Research, Education and Extension Organization (AREEO), Pub.

Rana, K. (1988). Reproductive biology and the hatchery rearing of tilapia eggs and fry. (Pp343- 406), ed. J. F. Muir, & R. J. Roberts. *Recent Advances in Aquaculture* V3. London: Croom Helm.

Ridha, M. T., & 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., & 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.

Sarsangi, A. H., Mohammadi, M., Mashaii, N., Rajabipour, F., Bitaraf, A., Askari, M., Moazedi, J., Nezamabadi, H., & Hosseinzadeh Sahafi, H. (2012). Adaptation, growth and survival of tilapia (*Oreochromis niloticus*) in Bafgh brackish water. *Iranian Scientific Fisheries Journal, 21*(2), 23-30.

Schofield, P. J., Peterson, M. S., Lowe, M. R., Brown-Peterson, N. J., & 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.

Tahoun, A. M., Ibrahim, M. A. R., Hammouda, Y. F., Eid, M. S., Zaki El-Din, M. M. A., & Magouz, F. I. (2008). Broodstock age, stocking density and fecundity of Nile tilapia, *Oreochromis nilotics* (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., & Cawthraw S. (1989). Partner attack inhibition in the sexually monomorphic biparental cichlid Tilapia mariae. *Behaviour, 109*, 1-19.

Watanabe, W. O., Kuo, C. M., & 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., & 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.