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# REPRODUCTIVE PARAMETERS IN THE FINGERLING PRODUCTION OF TILAPIA *Oreochromis niloticus*: REVIEW

## PARÁMETROS REPRODUCTIVOS EN LA PRODUCCIÓN DE CRÍAS TILAPIA *Oreochromis niloticus*: REVISIÓN

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**Abstract**

Aquaculture contributes significantly to the food source for human consumption. Tilapia *Oreochromis niloticus* is one of the main fish in aquaculture production, so its reproduction phases are vital to ensure the quality and quantity of organisms available for production systems. The reproductive parameters in fish aquaculture activities, such as fertility, fecundity, egg diameter, gonadosomatic index, survival rate in larvae and fingerlings, among others, are relevant for an economically profitable and sustainable production, and these can vary according to the diet, environmental conditions, age, genetic characteristics of the fish or the quality of the water. Therefore, this document aims to identify the reproductive parameters that influence on the production of fingerlings tilapia to present a general description in a simple way of the different reproductive parameters involved in aquaculture production activities of fingerlings tilapia. A search of the information in the last 20 years incorporated in various specialized databases was carried out. In this research, information is compiled to date on the reproductive parameters in tilapia, the results indicate that there is no more important reproductive parameter than another, since it is a cluster of factors and synergy that intervene in reproduction, hence it is necessary to establish clear management plans and research in the production systems to improve and enhance their production. Knowing the reproductive parameters of tilapia can help reduce production costs, thus it is necessary to establish clear management plans and research in production systems to improve and enhance their production.

***Keywords***: Reproduction, fingerlings production, fertility, fecundity, fingerlings.

**Resumen**

La acuicultura contribuye de manera importante a la fuente de alimento destinado al consumo humano. La tilapia *Oreochromis niloticus* es uno de los peces principales de la producción acuícola, por lo que las fases de su reproducción son vitales para asegurar la calidad y cantidad de organismos disponibles para los sistemas de producción. Los parámetros reproductivos en actividades acuícolas de peces, como la fertilidad, fecundidad, diámetro de huevos, índice gonadosomático, tasa de supervivencia en larvas y alevines, entre otros, son de relevancia para una producción económicamente rentable y sostenible, y estos pueden variar según la dieta, condiciones ambientales, edad, características genéticas de los peces o la calidad del agua. Por lo anterior, este documento tiene como objetivo identificar los parámetros reproductivos que tengan una influencia en la producción de crías de tilapia presentar una descripción general de forma sencilla los diferentes parámetros reproductivos involucrados y de consideración en actividades de producción acuícola de crías de tilapia. Se realizó una búsqueda de la información en los últimos 20 años incorporada en diversas bases de datos especializadas. En esta investigación se recopila la información a la actualidad sobre los parámetros reproductivos en tilapia, y los resultados indican que no existe un parámetro reproductivo más importante que otro, ya que es un cúmulo de factores y sinergia que intervienen en la reproducción, por lo que resulta necesario establecer planes de manejo claro e investigación particular en los sistemas de producción para mejorar y potencializar su producción. El conocimiento de los parámetros reproductivos de la tilapia puede ayudar a disminuir los costos de producción para establecer planes de manejo claro e investigación particular en los sistemas de producción para mejorar y potencializar su producción.

***Palabras clave***: reproducción, producción de crías, fertilidad, fecundidad, alevines.

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# 1 Introduction

Tilapia (*Oreochomis niloticus*) is an economic important species in Mexico, with a production above 168 thousand tons live weight reported in 2018 (CONAPESCA, 2018). Tilapia is a favorable organism for aquaculture because of its characteristics, such as its wide range of tolerance to environmental variations, its easy reproduction and its potential for cultivation (El-Sayed, 2016). Tilapia cultivation has responded to the high-quality production of food at low cost in rural areas.

The reproductive behavior of tilapia differs from others. The reproductive activity of tilapias of the genus *Oreochromis* occurs throughout the year if the environmental conditions allow an early reproduction (Vega-Villasante et al., 2009), since sexual maturation occurs at sizes below the commercial size of 250g approximately, between 50 and 100g (El-Sayed, 2016). Differences in growth between males and females are observed, since males have a higher growth rate and greater efficiency in the feed conversion rate. For this reason, the application of hormonal treatments to freshly hatched fingerlings has allowed optimizing biomass yields obtained on a commercial scale.

It is not advisable to underestimate the importance of environmental stimuli on tilapia reproduction, such as photoperiod, temperature, water quality and good nutrition (Carrillo et al., 2009). Reproductive success in terms of fertility, percentage of larvae obtained, growth rate, survival, disease resistance and adult fish shape are determined by the genetic characteristics of the species (Perea-Ganchou et al., 2017). Therefore, it is very important to determine the reproductive parameters that may interfere with the production of tilapia *O. niloticus*.

Therefore, this document focuses on providing reproductive parameters that have influenced on the production of tilapia breeding, describing in a general way the parameters involved in production activities of tilapia breeding to contribute to a scientific basis orientation for aquaculture producers, academics, government agencies and the general public interested in aquaculture activities in reproductive phases, and to define controlled strategies for obtaining rearing of this aquaculture species.

# 2 Methodology

Descriptive bibliographic research was conducted using various specialized databases such as Web of Science, Redalyc, ELSEVIER, SciELO, ACS Publications, Dialnet, Scince.gov, as well as on the websites of government agencies and institutes within the aquaculture sector such as the National Commission for Fisheries (CONAPESCA) and the National Fisheries Institute (INAPESCA) of Mexico, and the World Organization for Agriculture and Food of the United Nations (FAO). The main search keywords used were tilapia, tilapia from the nile, *Oreochromis*, reproduction, reproductive parameters, reproduction in tilapia, tilapia characteristics, physiology of reproduction, etc., in Spanish and English. Approximately 300 documents were collected, from which a first filtering was performed, resulting 174 documents of related or complementary information, which were filtered a second time for the specific parameters of this review to the number within the selected years, resulting in 40 references.

# 3 Important characteristics of tilapia

Tilapia is a fish native to Africa, currently distributed in America, Southeast Asia, some countries in Europe and even Australia. It belongs to a group of fish from Jordan, Israel and Africa, and was dispersed, transported and adapted by almost all other regions of the world; its breeding was successful, so it was introduced into the tropical and subtropical regions of various countries (Zimmermann, 2005). In Mexico, tilapia was introduced in 1964 from the United States of America, which was reproduced in almost all areas of the country (INAPESCA, 2018).

It has become one of the most cultivated species worldwide due to its tolerance to environmental variations, which has allowed it to develop in poorly oxygenated waters, sweet or salt, has a rapid growth, high reproductive capacity and adaptation to live in captivity conditions, as well as high crop densities, besides providing nutritional food with good taste, little spine and affordable price (Oso et al., 2006; Vega-Villasante et al., 2009).

The ideal temperature for its breeding oscillates between 31 to 36°C (INAPESCA, 2018; FAO, 2022).

It is possible to grow its crop at intervals of 20 to 30°C, but it may not develop or may even die at temperatures of less than 15°C or above 40°C (Saavedra Martínez, 2006; FAO, 2022). Another factor influencing survival is pH, which can be optimal for the species if it is in a value range of seven and eight, if this value is at pH conditions equal to or less than five it generates a harmful environment for fish (INAPESCA, 2018).

For oxygen dissolved in water, the optimal values are in the range of five to six mg/L, while there could be serious growth damage between two to three mg/L; and values equal to or less than one are critical, which can lead to death. As for turbidity, it is recommended to maintain a visibility of 30 cm depth (Saavedra Martínez, 2006).

Its growth is accelerated, reaching 500-680g in six to nine months according to the cultivation system used (Noriega-Salazar et al., 2020; FAO, 2022). Globally, it is one of the most studied fish, both in its life cycle as well as in its type of nutrition, eating habits, type of reproduction, disease resistance and handling, which facilitates its proliferation and handling in farming systems (Saavedra Martínez, 2006; FAO, 2022). Tilapias belonging to the genus *Oreochromis* have an omnivorous diet, making it possible for them to ingest algae, small aquatic organisms, roots, zooplankton, insects, bacteria, among other things (Vega-Villasante et al., 2009).

They also facilitate the filtering process with branchiospins, which allows them to eat the food (Nasrin et al., 2021). When swallowing the food it must pass through the pharynx of the fish, where it is crushed in the pharyngeal teeth, so that later it can continue with the digestion process (Yem et al., 2020). The type of food in crops can vary, reaching annual yields of between 5 tons/ha or more (FAO, 2022).

# 4 Reproductive features

## 4.1 Reproductive features of *O. niloticus* tilapia

As for sexual dimorphism, males have two orifices located in the caudal area, which are composed of the anus and the urogenital orifice, while the female has three orifices near the caudal area, these would be the anus, the genital pore and the urine excretory orifice or urinary orifice (Hussain, 2004; Saavedra Martínez, 2006). Urogenital orifice in males is a tiny point, and its urinary orifice in females is microscopic; a good way to differentiate the sexual genera of tilapias consists in identifying the genital pore in the female, which is located in a slit, perpendicular to the axis of the body (Saavedra Martínez, 2006) (Figure 1).

Sexual maturity occurs from five to six months, and although this is also related to weight it is known that sexual maturity in tilapias can be reached from 30g from two to four months if environmental conditions are favorable. Once females reach size for maturity, they can spawn eight to 12 times per year, depending on the temperature and other conditions (INAPESCA, 2018).

Spawning usually begins when the temperature reaches about 24°C, however, reproduction in natural environments takes place when the male first establishes an area and creates a hole for a nest. Later, he dedicates to watch over the nest until the female comes to spawn, so that the male fertilizes the eggs laid by the female, and once these have been fertilized by the male, the female places the eggs inside her mouth (oral incubation) and then she leaves with them (Vega-Villasante et al., 2009).

The female keeps the eggs in her mouth for hatching for one or two weeks (INAPESCA, 2018). Once pups are released from the eggs they can leave the mother's mouth, but if they are threatened by some danger, they tend to re-enter (INAPESCA, 2018; FAO, 2022).

The number, volume, and size of eggs a female can spawn depends on the mother's size. It is estimated that a female weighing up to 100 g may spawn approximately 100 eggs, but if her weight increases over a range of 600 to 1000g, the number of eggs she can spawn will increase from 1000 to 1500 (Perdomo et al., 2020; FAO, 2022). The same occurs under culture conditions, i.e., males can reach sexual maturity between four to six months, while females between three and five months.

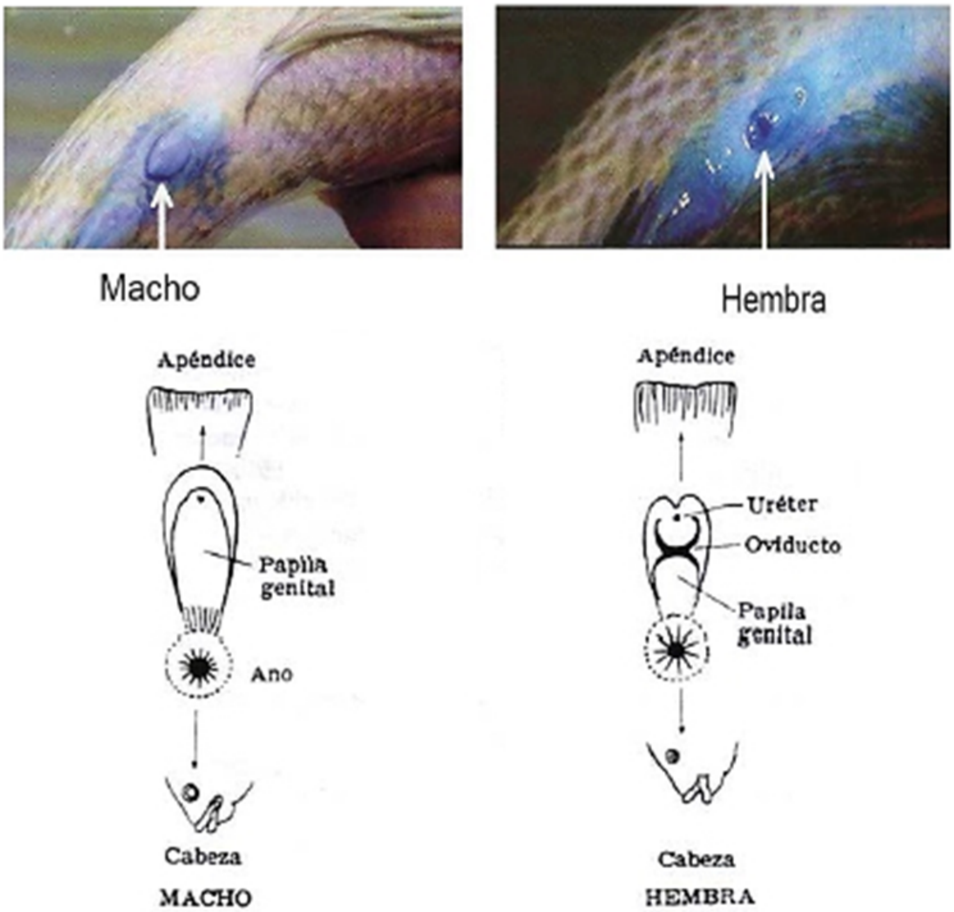


**Figure 1.** External morphological characteristics of sexual dimorphism of *O. niloticus* (Huet, 1998; Saavedra Martínez, 2006).

## 4.2 Reproductive evaluation

Reproduction is a mechanism used by living beings to maintain the prevalence of their species. Each organism has its reproduction strategies, and its success depends on the reproductive traits of each individual, which are stipulated by the genetics. In the case of farmed fish, reproduction is primarily defined by local environmental conditions and available infrastructure (FAO, 2022).

Fertility in fish is one of the most important data for reproduction in captivity, since it is possible to determine with this information the amount of eggs that a female can produce, i.e., it is used to calculate the reproductive potential of a fish population and survival from egg to recruitment, while fertility helps to know how many of the eggs produced will survive, therefore, fertility is the ability of females and males to conceive viable offspring (FAO, 2022; Zimmermann, 2005).

Another important data in the reproduction of fish is the hatching rate, making it possible to know the potential spawners have to produce viable eggs. The hatching rate refers to how many of the eggs produced and fertilized can hatch, since eggs can often be affected by various variables, compromising their viability and preventing hatching (Anene and Okorie, 2008; Abarike and Ampofo-Yeboah, 2016).

**Table 1.** Studies of reproductive parameters of tilapia (*O. niloticus*) and its relationship with environmental variables, fish age, absolute fecundity (Fa), relative fecundity (Rf), dissolved oxygen (DO), Chlorophyll a (Chl a), weight of the gonads (Pg), total body weight (Tbw) and gonadosomatic index (GSI).

| Author(s): | Reproductive parameters studied | Method | Contribution |
|---|---|---|---|
| Costa and Carvalho (2012) | 1-GSI | 1-Effect of physicochemical and environmental variables. 2.-Spearman correlation to detect relationships with physicochemical variables measured | 1-GSI values were positively related to pH, DO, conductivity, water transparency and Chl a. GSI values showed a response to the hydrological cycle, with a two-month delay for increases and decreases in values. |
| Massako et al. (2015) | 1-Spawning frequency 2-Number of eggs per spawning. | 1-In situ verification once a week and statistical model of eggs/female, according to the ages of females (1, 2 and 3 years). 2-Volume. | 1-The spawning frequency was higher in 3-year-old females, with a total of 3.49, while 2-year-old females only had a value of 0.80 at site 2, and 1.53 at site 1. 2- One-year-old females with fewer eggs (13 435 and 16 105 eggs) than those of 2 years (43 395 and 24 650 eggs). |
| Abarike and Ampofo-Yeboah (2016) | 1-GSI 2-Development of gonads 3-Fertility | 1-The following formula was performed: GSI=Gw/Ptc*100. 2-Direct observation. 3- Fertility vs. body length was calculated using the Fertility-Total Length ratio | 1-The highest GSI was recorded at higher temperature. 2-Only 20% of females were loaded, and the following stages were identified in their ovate: -Immature (white) = 7.14% January 2007.-Maturing (yellow) = 7.14% March 2007.-Mature (deep green) = 50% April 2007-Spent (Red, floppy) = 35.7% March 2007. 3-0% fertility in the cold months (nov-feb). 4.-The correlation between fecundity vs. body length was higher than the correlation between fecundity vs. body weight. The average fecundity was 173 oocytes. |
| Sièfo et al. (2018) | 1-Fertility 2-GSI | 1-Fa: Number of oocytes in ovaries. 1-Fr: Ratio of absolute fecundity to total body weight of the sample. 2-GSI: Ratio of gonad weight to gutted body weight. | 1-Average absolute fecundity was 412 and ranged between 174 and 593. Relative fecundity ranged from 3 to 9 oocytes per gram of body weight, with an average of 6 oocytes/g. 2-The highest percentage of GSI for females occurred between the warmest months (April and July). |
| Teame et al. (2018) | 1-Size of first maturity 2-GSI 3-Fertility | 1-Direct observation 2-It was calculated as the percentage of the weight of the gonads with respect to the total weight of the fish 3-Direct counting and statistical analysis | 1-The smallest sexually mature male measured 14cm, and the female measured 12.5cm. Sexual maturity in males (50%) was 15cm, and females 14cm. 2-Males and females followed almost the same trend. Males had higher average values in July, and females in August. Two peaks of GSI values were recorded in females during February and August, indicating that females can reproduce more than once a year3-It was estimated for 30 females a total size of 14cm up to 37cm, and with a weight of 78.8 to 711g. The total number of eggs ranged from 399 to 2129, the fecundity ranged from 104 to 709 eggs corresponding to fish with sizes from 12.5 to 20.9cm. Fertility ranged from 243 to 847 eggs per fish |
| Tessema et al. (2019) | 1-Fertility 2-GSI | 1-Fa was determined gravimetrically and statistically with 2-way ANOVA 2-Size-weight ratio of fish | 1-The average Fa was 217 eggs/fish and was positively correlated with the total length, total weight and weight of the gonads. 2-GSI values of males and females were highest in April and lowest in February. The highest average value in females was 2.6 in April, and 0.7 for males in the same month |

**Table 2.** Studies of reproductive parameters and their relationship with diets implemented in tilapia (*O. niloticus*) and their relationship with genetic characteristics, Relative Number of Eggs Being (NRH), Spawning Index (ID), Absolute Fertility (Fa) and Relative Fertility (Rf).

| Author(s): | Reproductive parameters studied | Method | Results |
|---|---|---|---|
| Quốc et al. (2013) | 1-Fr<br>2-Fertilization rate | 1-Females belonging to generation 12 of the tilapia GIFT strain were used in the Vietnam Mekong delta, where they were divided into 4 experiments named as "FAM" (Family), "MM" (Multiple Males and Multiple Females), "SM-1" (Single Male and Multiple Females) with a repetition called "SM-2"<br>2-Fr was calculated by the total number of eggs per female/Body weight of spawned females<br>3-Fertilization rate was calculated as 100*total number of eggs fertilized per female/total number of eggs per female | 1-Females in MM and SM-1 on average had the highest values of Fr2. In general, the fertilization rate was good, ranging between 77 and 87%. |
| Bizarro et al. (2019) | 1-GSI | 1-150 fingerlings of *O. niloticus* GIFT were exposed to different light intensities.<br>1-GSI calculated by gonad weight/body weight*100 | 1-GSI did not vary much with respect to the photoperiod |
| Silva et al. (2020) | 1-Fa and Fr<br>2-ID<br>3-Hatching rate<br>4-NRH | 1-Tilapias of the variation "Aqua America" and "GIFT" tilapias were used, making a cross between them to create 4 experiments with the following tilapias: Aqua America non-inbred, Aqua America inbred, GIFT and Aqua America×GIFT<br>2-Fa was calculated with the number of eggs per spawning, while Fr was calculated with the number of eggs per spawning/g female weight<br>3-The ID was calculated with the total weight of eggs per spawning in g / female weight in g*100 -%<br>4-The hatching rate was calculated with number of hatched larvae in the sample/ total number of eggs and larvae in the sample] * 100 -%<br>5-The NRH was calculated with the number of eggs/g of eggs | 1-The highest values of Fa were found in the Aqua America×GIFT genetic group, having a value of 7084.3, while the genetic group with the lowest value was found in GIFT, having a value of 2581.1. The highest Fr values were found in the Aqua America×GIFT genetic group, having a value of 5.4, and the lowest value was found in the GIFT genetic group; obtaining a value of 2.2<br>2-The highest and lowest valuesof ID were 3.0 and 0.9 respectively, and were found in the genetic groups of Aqua America×GIFT and Aqua America endogamous, respectively<br>3-The highest and lowest Hatching Rate values were 99.2 and 93.0 respectively, belonging to the non-inbred Aqua América and Aqua América×GIFT genetic groups, respectively<br>4- The highest and lowest valuesof NRH were 247.6 and 168.8 respectively, and were found in the genetic groups of non-endogamous Aqua America and Aqua America×GIFT.<br>5-The Fa, Fr, ID and hatching rate did not differ significantly between the genetic groups |

One of the great challenges in aquaculture is to be able to control reproduction effectively, since this physiological process has a marked seasonal characteristic, which is interpreted by specific sensory systems that culminate in a hormonal cascade mediated by the endocrine system (Carrillo et al., 2009). The goal is that reproduction occurs in the most favorable place and time for the survival of the progeny, but in almost all cases it is random due to the lack of control of some components (Navas, 2009). The main disadvantages faced in this process are the changes in the natural environmental conditions, reason for which they are programmed in production systems.

**Table 3.** Studies of reproductive parameters and their relationship with the diets implemented in tilapia (*O. niloticus*), Total Egg Weight per Female (PTHH), Number of Eggs per Gram (NHG), Spawning Index (ID), Survival During the Lecitotrophic Period (SPDL), Body Weight (BW), Absolute Fertility (Fa) and Relative Fertility (Rf).

| Author(s): | Reproductive parameters studied | Diet | Method | Contribution |
|---|---|---|---|---|
| Moraes et al. (2014) | 1-Fa and Fr<br>2-Diameter egg<br>3-Fasting larval survival capacity | 5 servings of crude protein at 32, 34, 36, 38 and 40%, one for each treatment | 1- The number of eggs per spawning was counted to calculate the Fa, and the total number of eggs per gram of body weight of the female was counted to calculate the Fr.<br>2-100 eggs were measured for each treatment, using a stereoscopic microscope with micrometric ocular microscope.<br>3-2000 larvae were collected per treatment for 3 days to evaluate the effect of the rations provided to the fingerlings on the survival time of the fasting. | 1-The highest values of Fa and Fr were found in the diet of 38% crude protein, and the lowest in the diet of 32%.<br>2-The highest values of egg diameter were found in the diet of 38% crude protein, and the lowest in the diet of 32%.<br>3-The highest value of the larval survival capacity in fasting was in the diet with 38% crude protein, while the lowest value was found in the diet with 32% crude protein. |
| Mehrim et al. (2015) | 1-Fa and Fr<br>2-Number of eggs | 8 treatments with a brand name hydroyeast with 0, 5, 10 and 15g of hydroyeast/kg diet, male and female. | 1-Fa was calculated using the following equation: Fa= PTHH (g)*NHG, and Fr was calculated using the following equation: Fr= Fa/PC (g).<br>2- The number of eggs was counted per gram of eggs and then related to the weight of the ovary or the body weight of the fish. | 1-The Fa and Fr was higher in the treatment with basal ration + 10 g of hydroyeast / kg diet for females, having a value of 3,416.6±97.95 and 20.6±1.13 respectively.<br>2-The number of eggs was also higher in the treatment with basal ration + 10g of hydroyeast/kg diet with a value of 325.00±14.43, while the lowest value was 250.00±28.86 in the treatment of basal ration + 15g of hydroyeast/kg diet. |

One of the alternatives to know the conditions in which reproduction in fish takes place are reproductive evaluations, which refer to trying to understand the environmental and biological requirements of fish through studies and experiments to guarantee their healthy reproduction, and thus generate an optimal number of viable gametes that promote fertilization, so that embryogenesis can be achieved, culminating in the hatching of eggs that will give origin to progeny (Carrillo et al., 2009). These have many applications that must consider not only reproduction but also the nutritional part to avoid diseases or malformations that could result from a nutritional unleveling that participates directly or indirectly in the processes of reproduction, development and survival (Navas, 2009).

Reproductive evaluations consider physical and chemical factors that limit their development, such as feeding, the number of individuals that should be in a population to avoid stress caused by a high sowing density, water quality and crop safety. Biological factors should also be considered such as the physiology of the fish, its behavior in relation to individuals of the same species or different species, among others (Elgaml et al., 2019).

As for the reproduction of species, its commercial or conservation value should also be considered because meeting the requirements that tilapia need to achieve reproduction can cause a decrease in profit and / or can permit having a projection of the investment needed and ensure the profitability of the crop. This can be estimated by relating the qualities of the fish such as fertility, fecundity, survival rate of larvae, as well as the number of eggs per spawning, which can give an estimate of the number of pups after the reproduction of the fish, as well as the estimated size that they could reach, guaranteeing an optimal production level according to the economic objectives estimated for the crop, which could drive to increased profits.

Regarding conservation, the reproductive evaluation could impact positively to rescue endangered species or under special conservation category (Mair et al., 1997; Anene and Okorie, 2008; Peña et al., 2010; Ramos de Alvarenga et al., 2017).

## 4.3 Overview of evaluations and studies of reproductive parameters in tilapia

Reproductive research has been conducted, including environmental variables or age (Table 1), genetic qualities (Table 2), diet (Tables 3 and 4), and water quality (Table 5), including, but not limited to, the fertility rate, survival rate, number and size of eggs per lay.

**Table 4.** Table 3 continued. Studies of reproductive parameters and their relationship with the diets implemented in tilapia (*O. niloticus*).

| Author(s): | Reproductive parameters studied | Diet | Method | Contribution |
|---|---|---|---|---|
| Orlando et al. (2017) | 1-Fa and Fr<br>2-ID | 5 diets with different levels of digestible energy (3200, 3400, 3600, 3800 and 4000 kcal/kg) | 1-Fr was calculated with the number of eggs per gram of female weight, and Fa was calculated with the total number of eggs per spawning.<br>2-The ID was calculated with the spawning weight per gram of the female. | 1-The values of Fa were higher with the diet of 4000 kcal / kg having a value of 449.32±13.48. The lowest value was found in the diet of 3400kcal / kg with a value of 348.50±10.00. In Fr the highest value was in the diet with 4000kcal/kg with a value of 6.57±0.23, while the lowest value was found in the diet with 3400kcal/kg, and had a value of 5.10±0.15.<br>2-The highest value of DI was found in the diet with 4000kcal/kg and the lowest in the diet with 3400kcal/kg, the values were 9.43±1.23 and 5.48±0.35, respectively. |
| Sarmento et al. (2018) | 1-Fa and Fr<br>2-SDPL<br>3-Hatching rate<br>4-Average egg production per female | Diets were implemented with vitamin C supplementation concentrations at 0, 261, 599 and 942 mg/kg of diet. | 1-Fa was calculated with the number of eggs in the spawning. Fr was calculated with the number of eggs/weight of the female(g).<br>2-The SDPL was calculated with the total number of larvae after 120 h/number of larvae after hatching*100<br>3-The hatching rate was calculated with the number of hatched larvae/total number of eggs*100<br>4- The average egg production per female was calculated with the number of eggs per lot/number of spawned females | 1-The highest value of Fa was found in the diet with 942 mg/kg of diet and had a value of 892.7±352.19, while the lowest value was found in the control (0 mg/kg of diet) with a value of 622.6±192.18. The highest value of Fr was found in the diet with 599 mg/kg of diet, and had a value of 10.09±2.93, while the lowest value was found in the control, and had a value of 3.61±1.56.<br>2-SPDL had the highest value in the diet with 599 mg/kg of diet<br>3-The highest hatching rate was 942 mg/kg diet<br>4-The average egg production per female had a higher value in the concentration of 599 mg/kg of diet. |

It is necessary to know the reproductive functions of fish to guarantee a good tilapia production, reason for which it is essential to know the physicochemical variables and biology that affect their reproduction. Aquaculture producers in Mexico and the world are limited in technology and knowledge to be able to regulate these variables, and thus be able to optimize reproduction (Ramos de Alvarenga et al., 2017).

The reproductive parameters of *O. niloticus* change depending on the variables they are exposed to, and the reproductive parameters can be affected in a negative or positive way depending on the variable. An example is age, where according to Massako et al. (2015), 3-year-old females had a higher frequency of spawning than 2-year-old, differing somewhat by Tsadik Getinet (2008), who mentions that the half-life of spawners in tilapias can be up to 3 years, so it would be expected that the older spawners the lower reproductive parameters, but it is not the case.

Regarding its relationship with nutrition, reports indicate that a nutritious and well-balanced diet greatly favors the reproductive qualities in tilapia and in turn improves health, preventing some diseases, although an excess of nutrients in the diets could reduce reproductive parameters. Chong et al. (2004) mention that diets with high protein content can be beneficial for the processes related to the reproduction of fish, as long as it is well balanced.

In turn, many eggs do not always mean a larger number of fish, as fertility and the hatching rate also depend on genetic characteristics (Sun et al., 2009). Artificial selection has proven to be a key component for improving reproduction in fish, as well as aspects related to aquaculture production, but as mentioned by Camero-Escobar and Calderón-Calderón (2018), the implementation of new technologies without supervision, such as artificial selection, could have negative effects on fish and in the production systems.

Having a good water quality is an essential part in the reproduction of tilapia, more often the sources where water is obtained for fish farming are compromised by pollutants that affect both health and reproduction, so it is important to have a good quality of water free of pollutants (Elgaml et al., 2019), since this is one of the main resources in aquaculture. Therefore, a good supply of clean water can prevent the loss of fish by pollutants or any other substance that could contain water (Gerbron et al., 2014).

**Table 5.** Studies on reproductive parameters in tilapia (*O. niloticus* and its relationship with water quality, absolute fertility (Fa), relative fertility (Rf) and gonadosomatic index (ID).

| Author(s): | Reproductive parameters studied | Method | Results |
|---|---|---|---|
| Zulfahmi et al. (2018) | 1-GSI<br>2-Fa and Fr | 1-Exposure to concentrations of palm oil manufacturing effluent (Control= 0 mg/L, A= 1.565 mg/L, B= 2.347 mg/L and C= 3.130 mg/L).<br>2-GSI calculated with gonad weight/total body weight*100.<br>3-Fa was calculated with the partial number of eggs in gonads/partial weight of the gonads*weight of the gonads. Fr was calculated with body weight/total number of eggs in the gonads | 1-The highest mean values of GSI were found in treatment B (6,007±2,78 %). GSI values tended to increase in treatments A and B compared to control treatment, then decreased in treatment C (2.446±0.46 %). There were no significant differences between GSI values for treatment control, treatment A and treatment B.<br>2-The highest average value of Fa was obtained in the treatment A (520±254 eggs), while the lowest value was in the treatment B (307±57 eggs). Although the Fa value for treatment C was higher than that of treatment B. However, treatment C has a lower Fr than treatment B. Exposure to palm oil production effluent did not reveal significant differences in Fa and Fr. |

# 5 Conclusions

Knowing the reproductive parameters of tilapia can help reduce production costs and although there is not a reproductive parameter more important than another, there are factors and synergy involved in the reproduction. It is necessary to establish clear management plans and research on production systems to improve and enhance production. The evaluation of the reproductive parameters of *O. niloticus* tilapia can help reducing the production costs at the time of investing in a crop, since knowing the requirements of the species can help obtaining a better result in this phase. It is suggested to conduct more research to evaluate the reproductive parameters, but even though there is enough information in the topic, there is not enough support, hard data and the interaction of the variables involved in the process.

## References

Abarike, E. and Ampofo-Yeboah, A. (2016). Reproductive potential of nile tilapia (*Oreochromis niloticus* linnaeus, 1757) in the golinga reservoir in ghana. *International Journal of Fisheries and Aquatic Studies*, 4(5):279–283. Online:https://bit.ly/41xMmI2.

Anene, A. and Okorie, P. (2008). Some aspects of the reproductive biology of tilapia mariae (boulenger 1901) in a small lake in southeastern nigeria. *African Journal of Biotechnology*, 7(14):2478–2482. Online:https://acortar.link/YKQqCt.

Bizarro, Y. S., Navarro, F., Ribeiro, O., and Navarro, R. (2019). Photoperiodic effects in blood glucose, cortisol, hematological parameters and reproductive indexes of gift lineage reversed male tilapia. *Bioscience Journal*, 35(6):1915–1922. Online:https://acortar.link/SNd54J.

Camero-Escobar, G. and Calderón-Calderón, H. (2018). Vigilancia tecnológica e inteligencia competitiva para la producción de tilapia roja (*Oreochromis mossambicus*) en el departamento del huila, colombia. *Revista de Investigación, Desarrollo e Innovación*, 9(1):19–31. Online:https://acortar.link/yAYwr9.

Carrillo, M., Zanuy, S., and Bayarri, M. (2009). *El control ambiental de la reproducción de los peces con especial referencia al control del ciclo sexual, de la pubertad y de la precocidad*, chapter La reproducción de los peces: aspectos básicos y sus aplicaciones en acuicultura, pages 173–233. Publicaciones científicas y tecnológicas de la Fundación Observatorio Espanol de Acuicultura.

Chong, A., Ishak, S.and Osman, Z., and Hashim, R. (2004). Effect of dietary protein level on the reproductive performance of female swordtails xiphophorus helleri (poeciliidae). *Aquaculture*, 234(1-4):381–392. Online:https://bit.ly/3V7qAsm.

CONAPESCA (2018). Anuario estadístico de acuacultura y pesca 2018. Technical report, Comisión Nacional de Acuacultura y Pesca.

Costa, J. and Carvalho, E. (2012). Reproduction, food dynamics and exploitation level of *Oreochromis niloticus* (perciformes: Cichlidae) from artisanal fisheries in barra bonita reservoir, brazil. *Revista de biologia tropical*, 60(2):721–734. Online:https://acortar.link/B9VSQX.

El-Sayed, A. (2016). *Tilapia culture*. CAB Int. Oxfordshire, UK. Online: https://acortar.link/zinHtL.

Elgaml, S., Saad, T., Hamed, M., and Zaki, V. (2019). Effects of heavy metal pollutants on the reproduction of nile tilapia. *Int j Fish Aquat*, 7(5):542–547. Online:https://bit.ly/3oDKsqI.

FAO (2022). *Oreochromis niloticus*. FAO0. Online:https://acortar.link/1GN9Ck 0.

Gerbron, M., Geraudie, P., Fernandes, D., Rotchell, J., Porte, C., and Minier, C. (2014). Evidence of altered fertility in female roach (rutilus rutilus) from the river seine (france). *Environmental pollution*, 191:58–62. Online:https://acortar.link/WVWajE.

Huet, M. (1998). *Tratado de piscicultura*. Mundi-Prensa.

Hussain, M. (2004). Farming of tilapia, breeding plans, mass seed production and aquaculture techniques. Technical report, Bangladesh Fisheries Research Institute, Bangladesh, India. Online: https://acortar.link/eZnleQ.

INAPESCA (2018). Acuacultura tilapia. Instituto Nacional de Pesca0. Online:https://acortar.link/hNiQHS0.

Mair, G., Abucay, J., Abella, T., Beardmore, J., and Skibinski, D. (1997). Genetic manipulation of sex ratio for the large-scale production of all-male tilapia *Oreochromis niloticus*. *Canadian Journal of Fisheries and Aquatic Sciences*, 54(2):396–404. Online:https://acortar.link/SeNd0c.

Massako, G., Lopes, C., Miwa, N., Soriani, G., and Pereira, R. (2015). Reproduction performance of female nile tilapia under different environments and age classes. *Acta Scientiarum. Animal Sciences*, 37:221–226. Online:https://acortar.link/ja9Iud.

Mehrim, A., Khalil, F., and Hassan, M. (2015). Hydroyeast aquaculture® as a reproductive enhancer agent for the adult nile tilapia (*Oreochromis niloticus* linnaeus, 1758). *Fish Physiology and Biochemistry*, 41:371–381. Online:https://acortar.link/WSJY9O.

Moraes, M., Ribeiro, T., Maria, T., Garcia, D., Martins, M., Fonseca, R., and Vieira, P. (2014). Effects crude protein levels on female nile tilapia (*Oreochromis niloticus*) reproductive performance parameters. *Animal Reproduction Science*, 150(1-2):62–69. Online:https://acortar.link/Sz8g5H.

Nasrin, S.and Rahman, M., Awal, M., Das, M., Hossain, M., and Sarker, F. (2021). Effect of feeding frequency on the growth of gift (*Oreochromis niloticus*). *International Journal of Fisheries and Aquatic Studies*, 9(2):98–107. Online:https://acortar.link/v7ruUM.

Navas, J. (2009). *La reproducción de los peces: aspectos básicos y sus aplicaciones en acuicultura*, chapter Capitulo 8. Los perturbadores endocrinos y sus posibles efectos en la reproducción de peces cultivados, pages 531–580. Publicaciones científicas y tecnológicas de la Fundación Observatorio Espanol de Acuicultura.

Noriega-Salazar, A., Rivas-Salazar, D., Silva-Acuña, R., and Hurtado, E. (2020). Crecimiento y sobrevivencia de juveniles de tilapia roja con dietas suplementadas de vitaminas c y e. *Revista Ciencia UNEMI*, 13(34):16–27. Online:https://acortar.link/lkyePL.

Orlando, T., de Oliveira Moraes, M., Paulino, R., Costa, A., Allaman, I., and Rosa, P. (2017). Reproductive performance of female nile tilapia (*Oreochromis niloticus*) fed diets with different digestible energy levels. *Revista Brasileira de Zootecnia*, 46:1–7. Online:https://acortar.link/EfIWUC.

Oso, J., Ayodele, I., and Fagbuaro, O. (2006). Food and feeding habits of *Oreochromis niloticus* (l.) and sarotherodon galilaeus (l.) in a tropical reservoir. *World Journal of Zoology*, 1(2):118–121. Online:https://acortar.link/Ap2Zpl.

Peña, E., Tapia, R., Velázquez, J., Orbe, A., and Ruiz Velazco, J. (2010). Growth, mortality and reproduction of the blue tilapia *Oreochromis aureus* (perciformes: Cichlidae) in the aguamilpa reservoir, mexico. *Revista de biología tropical*, 58(4):1577–1586. Online:https://acortar.link/6vYvD6.

Perdomo, D., Corredor, Z., Reyna, Y., González, M., Moratinos, P., and Perea, F. (2020). Influencia del tamaño, la variedad y la proporción de sexos en la producción de huevos de tilapia (*Oreochromis* spp) en un sistema tropical intensivo al aire libre. 31(4):e19037. Online:https://acortar.link/vZr0nP.

Perea-Ganchou, F., Perdomo-Carrillo, D., Corredor-Zambrano, Z., Moreno-Torre, R., Pereira-Morales, M., and González-Estopiñán, M. (2017). Factores que afectan el desempeño reproductivo de tilapias del género *Oreochromis* en la zona baja del estado trujillo, venezuela. *Revista Científica*, 27(2):78–86. Online:https://acortar.link/tIxIQP.

Quốc, T., Van-Arendonk, J., , and Komen, H. (2013). Genetic parameters for reproductive traits in female nile tilapia (*Oreochromis niloticus*): Ii. fecundity and fertility. *Aquaculture*, 416–417:72–77. Online:https://acortar.link/x4lds4.

Ramos de Alvarenga, É., Moreira de Sales, S., Soares de Brito, T., Santos, C., Dias Serafim Corrêa, R., de Oliveira Alves, G., Guimarães Manduca, L., and Maldonado Turra, E. (2017). Effects of biofloc technology on reproduction and ovarian recrudescence in nile tilapia. *Aquaculture Research*, 48(12):5965–5972. Online:https://bit.ly/3Lm47TZ.

Saavedra Martínez, M. (2006). *Manejo del cultivo de tilapia*. USAID-CIDEA. Online:https://acortar.link/gac8mw0.

Sarmento, N., Martins, E., Costa, D., Mattioli, C.and da Costa Julio, G., Figueiredo, L., Luz, M., and Luz, R. (2018). Reproductive efficiency and egg and larvae quality of nile tilapia fed different levels of vitamin c. *Aquaculture*, 482:96–102. Online:https://acortar.link/zD8Dqr.

Sièfo, G., Adama, O., Awa, N., Awa, G., Wendengoudi, G., Papa, N., and Gustave, K. (2018). Some reproductive aspects of *Oreochromis niloticus* (linnaeus, 1758) at peele reservoir, nakanbé river basin, burkina faso. *International Journal of Fisheries and Aquatic Studies*, 6(4):124–130. Online:https://acortar.link/UEDLWs.

Silva, A., Corrêa, R., Ventura, A., Nunes, A., Laice, L., Ribeiro, R., Oliveira, C., Almeida, L., Barbosa, P., and Povh, J. (2020). Reproductive traits in different nile tilapia genetic groups. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 72:1797–1804. Online:https://acortar.link/qT5A95.

Sun, C., Madsen, P., Nielsen, U., Zhang, Y., Lund, M., and Su, G. (2009). Comparison between a sire model and an animal model for genetic evaluation of fertility traits in danish holstein population. *Journal of Dairy Science*, 92(8):4063–4071. Online:https://acortar.link/v6pJ3q.

Teame, T., Zebib, H., and Meresa, T. (2018). Observations on the biology of nile tilapia, *Oreochromis niloticus* l., in tekeze reservoir, northern ethiopia. *International Journal of Fisheries and Aquaculture*, 10(7):86–94. Online:https://acortar.link/InIM0K.

Tessema, A., Getahun, A., Mengistou, S., Fetahi, T., and Dejen, E. (2019). Length-weight relationship, condition factor and some reproductive aspects of nile tilapia (*Oreochromis niloticus*) in lake hayq, ethiopia. *International Journal of Fisheries and Aquatic Studies*, 7(5):555–561. Online:https://acortar.link/ak7Tga.

Tsadik Getinet, G. (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. Online:https://acortar.link/zEylZE.

Vega-Villasante, F., Jaime-Ceballos, B., Cupul-Magaña, A., and Galindo-López, J. y Cupul-Magaña, F. (2009). *Acuicultura de tilapia a pequeña escala para autoconsumo de familias rurales y periurbanas de la costa del Pacífico*. Universidad de Guadalajara.

Yem, I., Bankole, N., Umar, R., Ibrahim, A., and Ewutanure, S. (2020). Food habit and growth pattern of nile tilapia *Oreochromis niloticus* in wase dam, nigeria. *Int. J. Fish. Aqua. Stud.*, (4):257–260. Online:https://acortar.link/1EqatL.

Zimmermann, S. (2005). *Reproducción de los peces en el trópico*, chapter Reproducción de la tilapia, pages 147–164. Ministerio de Agricultura y Desarrollo Rural, Instituto Colombiano de Desarrollo Rural.

Zulfahmi, I., Muliari, M., Akmal, Y., and Batubara, A. (2018). Reproductive performance and gonad histopathology of female nile tilapia (*Oreochromis niloticus* linnaeus 1758) exposed to palm oil mill effluent. *The Egyptian Journal of Aquatic Research*, 44(4):327–332. Online:https://acortar.link/nOZhYm.