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A Comparative Study Between the Growth Rates and Performance Efficiency of the Nile Tilapia Farmed in Lake Nasser and the Northern Delta: An Attempt to Improve its Aquaculture

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ABSTRACT

This study was conducted to investigate the growth rates and performance of the Nile tilapia from two distinct geographical regions while being cultivated under the same aquaculture conditions. Lake Nasser fish (LNF) were transported from Aswan south of Egypt to the Serw Fish Research Station (SFRS), located in the northern Delta, where acclimation process and rearing experiment was conducted. The average initial weight of fingerlings from both the LNF and Serw fish (SF) strains was 100 ± 15g. The fish were manually sexed and were stocked at a density of 5 fish per cubic meter in 15m³ triplicate groups of concrete tanks, with separate tanks for each sex, all under the same conditions of SFRS. Fish were fed 35% crude protein diet for 60 days. LNF was significantly better than SF in most growth performance parameters ($P \leq 0.05$). The average daily gain was significantly doubled in LNF than SF (3.21, 1.77, respectively), which leads to average weight of LNF almost 292.25g ($P \leq 0.05$). SGR and Fulton's condition factor were significantly higher in LNF than in SF, recording 2.06, 2.09 and 1.18, 1.77, respectively ($P \leq 0.05$). On the other hand, the survival rate of SF was higher than that of LNF. The reproductive efficiency parameters namely, absolute fecundity, relative fecundity to length, gonado-somatic index exhibited highly significant increase in LNF than in SF ($P \leq 0.05$). In conclusion, the present study revealed that the Nile tilapia inhabiting Lake Nasser has good characteristics that should attract the farmers and stakeholders. Partial exchange of the broodstock is recommended in the northern tilapia farms and hatcheries with the Lake Nasser tilapia to improve the aquaculture sector.

INTRODUCTION

The Nile tilapia (*Oreochromis niloticus*) ranks fourth of the major cultured aquatic animals in the world after shrimp, oyster, and carp with approximately 5.3×10^6 tons during 2022 **(FAO, 2024)**. In Africa, the Nile tilapia is the dominant aquacultured species of the total production, followed by the African catfish (*Clarias gariepinus*) **(FAO, 2024)**. Remarkably, Egypt produced 964,000 tons of the Nile tilapia in 2022, making it the only African country among the top ten producers of the Nile tilapia in the world

(FAO, 2024). The Nile tilapia constitutes about 70 percent of all fish farmed in Egypt **(GAFRD, 2019)**.

Fish production is dominated by the Nile tilapia, although several other tilapia species are farmed in Africa, including *O. mossambicus*, *O. aureus*, *O. andersonii*, *O. spirulus*, *O. esculentus*, *O. shiranus*, and *Coptodon zillii*. The red tilapia is a hyperdized species between the Nile tilapia and Mozambique tilapia (*O. mossambicus*), with the latter being farmed recently.

The popularity of the the Nile tilapia is attributed to its variety of diets, tolerance of the wide range of aquaculture conditions, rapid growth, being well accepted by consumers, capacity to reproduce in captivity, easiness to breed, tolerance to severe environmental parameters, in addition to being widely available to farmers **(Pullin *et al*., 1991; Charo-Karisa *et al.*, 2006; El-Sayed & Fitzsimmons, 2023)**. These attributes make the Nile tilapia suitable to be farmed in a wide range of water quality, such as temperature, salinity, pH, and low dissolved oxygen.

The global growth of fish production requires continuos exploitation of water resources, which can lead to corresponding growth in Africa and Egypt, in particular **(El-Otify, 2015)**. In Africa, the Nile tilapia is farmed with the African catfish in semi-intensive fertilized earthen ponds with supplementary feeding, either in monoculture or in polyculture **(Charo-Karisa *et al*., 2006; El-Sayed, 2008)**. The sustainability performance of tilapia production systems in Egypt is linked to variations in tilapia aquaculture production features and practices. The production from the monoculture systems was significantly higher than from the polyculture systems (10460.5, 8404.7 tons/ha; respectively), particularly in Kafr Elshikh (The most tilapia farming regions in northern Delta), as stated by **Rossignoli *et al*. (2023)**.

Lake Nasser is the largest man-made lake in the world, which has been formed after the construction of Aswan High Dam during the sixties of this century **(Elgamal & Zaki, 2017; Salih *et al*., 2019)**. Lake Nasser (the main channel) is the deepest area of the High Dam Lake, reaching a depth of about 180m, with distinct morphological characteristics. It is situated between Latitudes 22° 00 and 23° 58\ N and Longitudes 30° 35 and 33° 15\ E and occupies about 5237km^2 surface area and 300km in length, and the mean depth is about 30m **(Abd Ellah, 2020)**.

Numerous side extensions (embayments) were protracted from the main reservoir called “Khors”, which occupies 79% of the total surface of the lake, and they are highly productive in fisheries **(Entz, 1976)**. Lake Nasser and khors water have been characterized by relatively low nutrient concentrations and low heavy metal contamination in both water and sediment **(Goher *et al*., 2014; Abd Ellah & El-Geziry, 2016)**. The environment of the lake and khors is considered a suitable site for natural fish habitat because of the availability of large number of aquatic plants and plankton that gives good source of food for fish. Therefore, the environment of Lake Nasser is favorable for biological processes in general and particularly for fish production, in terms of breeding and feeding **(Imam *et al*., 2020; Salem & Mageed, 2021)**.

The mean fish production of Lake Nasser is about 28,000 tons annually, which constituted 18% of the total fish harvested from the Egyptian lakes **(Mehanna *et al*., 2021)**. The fish production at Lake Nasser reached its maximum in 1998, with more than 50,000 tons, then it started to decline steadily to less than 19,000 tons in 2016 **(GAFRD, 2018)**. The fish community of Lake Nasser comprises 52 species from 15 families **(Zwieten *et al*., 2011)**. The Nile tilapia forms a common population of fish species in Lake Nasser constituting about 19% of the lake's fish community **(Shallof *et al*., 2020; Goher *et al*., 2021)**. More recently, tilapias constitute about 67% of the fish production from khors **(GAFRD, 2018)**.

The global tilapia industry is facing multiple factors such as increased costs, fluctuating market demand, and production challenges. Egypt, as the largest producer in Africa and the third-largest producer globally, is facing supply stagnation due to rising costs following the COVID-19 pandemic. As a result, production in 2022 was lower than expected. Thus, there is a significant need to adjust national strategies to adapt to market changes and to seek new development opportunities **(Abdel-Hady *et al*., 2024)**.

Tilapia are known for their asynchronous breeding habits and low fecundity **(Ridha & Cruz, 2000)**. Thus, one of the main obstacles preventing the economic expansion of tilapia production is the lack of tilapia seeds **(El-Sayed & Fitzsimmons, 2023)**. Several environmental factors are affecting tilapia reproduction and seed production, such as sex ratio **(Toguyeni *et al*., 1997; Abouelfadl *et al*., 2024)**, stocking rates **(Ridha & Cruz 2000; Billah *et al*., 2020)**, photoperiod **(El-Sayed & Kawanna, 2007)**, broodstock exchange (rotation and rest) **(El-Ebiary *et al*., 2013; Addo *et al*., 2023)**, water temperature **(Abd El-Hack *et al.*, 2022)**, and salinity **(Yue *et al*., 2024; Watanabe *et al*., 2024)**. Under aquaculture circumstances, spawning efficiency can be enhanced by adjusting a few of these factors.

The broadstock exchange can be a key strategy to maximize tilapia reproduction and to maintain a constant supply of their seeds, particularly in in-door hatcheries **(El-Sayed & Kawanna, 2007)**. Some trials have been investigated to exchange broadstock in order to improve tilapia culture in Egypt, on both scales governmental and personal. One of the major achievements in the Nile tilapia breeding was the development of the genetically improved farmed tilapia (GIFT), created by the WorldFish Center (ICLARM) in the late 1980s **(Eknath & Hulata, 2009; Ali *et al*., 2017)**.

Therefore, the present study was implemented to assess the local needs of both the farmers and hatcheries through measuring growth rates and performance efficiency of Lake Nasser fish to be cultivated and to reproduce under the northern Delta aquaculture conditions, in comparison to the inhabited Nile tilapia.

MATERIALS AND METHODS

The experiment began with the collection of Nile tilapia fingerlings from the shores of Lake Nasser in May 2023. These fingerlings were then transported to the Serw Fish Research Station (SFRS), National Institute of Oceanography and Fisheries (NIOF), Damietta Governorate.

1. Fish transportation

The Lake Nasser fish (LNF) were placed in well-prepared, aerated, and sanitized tanks, filled to two-thirds of their volume with water to prevent turbulence during transportation. The fish were lightly anesthetized with 15µl of clove oil to reduce stress while being transported from Aswan in southern Egypt to Damietta, approximately 880km to the north **(Kaiser *et al.*, 2006)**. The journey took about 10 hours, from sunset in Aswan to sunrise in Damietta, to avoid thermal stress posed on the fish. Every two hours during this period, water from SFRS (10 liters per 1 m^3 tank) was added to the tanks. Upon arrival at SFRS, the fish were gradually acclimated by replacing the Lake Nasser water with SFRS water over a 72-hour period.

The fish were then rested in concrete under SFRS conditions for a week. During the rest period of LNF, same number and size of the Nile tilapia fingerlings were collected from SFRS, and stocked in the same conditions that LNF inhabited.

Table 1. Water quality parameters of Serw Fish Research Station (SFRS) and Lake Nasser during sampling of the studied fish in May 2023

	Serw Fish Research Station (SFRS)			Lake Nasser		
Parameter	**Avg**	**±**	**SD**	**Avg**	**±**	**SD**
T (°C)	26.8	±	0.2	29.8	±	0.2
PH	7.34	±	0.41	7.49	±	0.32
EC (mS/cm)	0.91	±	0.14	0.98	±	0.12
Sal	0.41	±	0.05	0.08	±	0.02
TDS (g/l)	0.48	±	0.03	0.53	±	0.14
DO (mg/l)	4.72	±	0.33	6.62	±	0.13
DO Saturation (%)	61.34	±	4.25	61.34	±	4.25
NH_3(mg/l)	0.17	±	0.05	0.092	±	0.02

2. Water quality parameters

Physicochemical parameters of SFRS water were weekly monitored during the experiment. DO was measured by a digital oxygen meter (YSI Model 58, USA). Water temperature (T), pH, and electrical conductivity (EC) were immediately measured onsite by using a portable multi-parameter water quality meter (Model C8GoT Consort, Belgium). The spectrophotometric method was used for ammonia (NH4-N) determination **(APHA, 2005)**. The average values of all parameters during the study are summarized in Table (1).

3. Fish rearing experiment

At the beginning of the experiment, fingerlings from both strains (LNF and SF) with an average initial weight of 100 ± 15 g were selected, manually sexed (by observing the genital papillae), and stocked in triplicate groups of concrete tanks (15 m³ each) with separate sexes (males alone and females alone) at a stocking density of 5 fish/m³ under SFRS conditions. Approximately, 10% of the water was replaced daily with fresh water from SFRS. The culture system was equipped with continuous aeration to maintain a good dissolved oxygen concentration throughout the day.

All fish groups were manually fed a commercial tilapia diet (35% crude protein) at a daily rate of 5% of their body weight, twice a day at 08:00 and 14:00, 7 days a week, for 60 days. The fish were weighed collectively at 10-day intervals, and their average weights were recorded to calculate growth rates. Daily rations were adjusted accordingly.

At the end of the experiment, the fish were netted, lightly anesthetized with a 50-µl clove oil solution, and random samples were collected, weighed individually, and their final average weights and lengths were recorded for both males and females.The growth rates, survival rate, and the reproductive fish performance parameters were calculated as follows:

3.1. Calculation of fish performance

Fish performance was evaluated for final weight (g), final length (cm), weight gain (g), weight gain (%), average daily gain (g), specific growth rate (%Day^{-1}), the Fulton's condition factor (K), and survival rate (%) according to the method of **El-Mezayen *et al.* (2024)**.

$$(a)\ Average\ daily\ gain\,(g) = \frac{W_2 - W_1}{t}$$

$$(b)\ Weight\ gain\,(\%) = \frac{W_2 - W_1}{W_1} X\ 100$$

$$(c)\ Specific\ growth\,rate\ (\%\text{Day}^{-1}) = \frac{\ln W_2 - \ln W_1}{t} X\ 100$$

$$(d)\ \text{Fulton's Condition Factor}\ (\%) = \frac{W2}{L3} \times 100$$

$$(e)\ Survival\ (\%) = \frac{number\ of\ fish\ harvested\ X\ 100}{number\ of\ fish\ stocked}$$

Where, W_1 = initial weight (g); W_2 = final weight (g); t = rearing duration (days).

3.2. Reproductive efficiency

The measurement of oocyte diameter was implemented on stage IV fish gonad development. Ovaries were fixed in 4% neutral formalin. For the estimation of fecundity, the number of oocytes measured for each fish consisted of 150 eggs using a microscope equipped with a micrometer (magnification 40).

The main reproductive performance parameters, namely the gonadosomatic index (GSI), fecundity and oocyte diameter were investigated according to **Zulfahmi *et al*. (2018)**. The total weights of the gonad and liver (g) were used to determine the hepato-somatic index (HSI) and gonad somatic index (GSI) of each fish by using the following formula:

(d) Gonado-somatic index $(\%) = \frac{Ovary\ weight}{W_2} \times 100$

(d) Hepato-somatic index $(\%) = \frac{Liver\ weight}{W_2} \times 100$

For fecundity estimation, the ovaries of mature females were weighed, divided to three sub-samples from each ovary and weighted. Absolute fecundity (F) was calculated as F = No. of opaque (mature) eggs in a subsample × (Weight of ovary/Weight of subsample) according to **Aly and Abouelfadl (2020)**. Relative fecundity in relation to gutted weight or total length groups to get number of eggs per gram body weight and per cm of the body length **(Ismail *et al*., 2016)**.

4. Statistical analysis

All results were expressed as the average (Avg) ± standard deviation (SD). Data on fish growth parameters were subjected to paired comparison using a t-test to calculate the probability (p-value) of no statistical difference between the two fish groups. The criterion for statistical significance in this study was set at the 95% confidence level ($P \leq 0.05$). SPSS software (Release 14.0; SPSS, Chicago, IL, USA) was used for analysis.

RESULTS AND DISCUSSION

The effect of the spatial environment on the Nile tilapia growth rates and performance efficiency was investigated by comparing two important aquaculture locations along the Nile River in Egypt. A comparison between Serw fish (SF) and Lake Nasser fish (LNF) in terms of weight gain (g), average daily gain (g), specific growth rate (%), Fulton's condition factor (%), and survival rate (%) is presented in Table (2).

The results indicated that LNF outperformed SF in most growth performance parameters throughout the study period. Average daily gain (ADG) differences between LNF and SF were highly significant ($P \leq 0.05$), with LNF showing nearly double the ADG of SF (3.21g/ day vs. 1.77g/ day). As a result, final weight, weight gain, and percent of weight gain showed highly significant increases in LNF, with averages of 292.25g, 192g, and 64.61%, respectively. In contrast, these values were only 206.25g, 106.25g, and 49.69%, respectively, for SF (Fig. 1).

Table 2. Growth parameters of the Nile tilapia (Avg ± SD) from the Serw Fish Research Station and Lake Nasser, both were reared under the Serw conditions for 60 days

Group	**Serw Fish-SF**					**Lake Nasser Fish-LNF**				
Parameter	**Avg**	**±**	**SD**	**Min**	**Max**	**Avg**	**±**	**SD**	**Min**	**Max**
FL (cm)	22.62	±	2.22	20.50	25.00	25.50	±	1.91	23.00	27.00
FW (g)	206.25	±	45.37	165.0	247.0	292.25	±	53.48**	241.1	346.0
WG (g)	106.25	±	45.37	65.00	147.0	192.25	±	53.5**	191.0	312.0
WG%	49.69	±	11.08	39.39	59.51	64.61	±	4.46*	53.64	76.73
ADG (g/day)	1.77	±	0.76	1.08	2.45	3.21	±	0.89**	2.37	4.20
SGR (%)	1.18	±	0.37	0.83	1.51	2.06	±	0.26*	1.78	2.36
K (%)	1.77	±	0.14	1.58	1.92	2.09	±	0.22*	1.85	2.39
SR (%)	97.50	±	0.57	97.00	98.00	96.75	±	0.96	96.00	98.00

Values with one asterisk (*) are statistically significant at $P \leq 0.05$.

Values with two asterisks (**) are statistically highly significant at $P \leq 0.05$.

FL: Final length**, FW:** Final weight, **WG:** Weight gain, **WG%:** Percent of weight gain**, ADG:** Average daily gain**, SGR:** Specific growth rate**, K:** Fulton's condition factor, **SR:** Survival rate

The availability of the formulated food in adequate quantity and quality, accompanied by the decreased energy loss and low metabolic rate in captivity of LNF may be key reasons for the significant increase in the weight of LNF. However it is the normal aquaculture conditions for the SF farming, in terms of food and energy, therefore no significant weight increase was noticed in SF parameters ($P \leq 0.05$).

SGR and Fulton's condition factor were also significantly higher in LNF than in SF recording 2.06, 2.09 and 1.18, 1.77, respectively (Table 2). This higher values reflects the high ability of LNF to adapt to the new spatial environment in different locations with different conditions than its' original habitat **(Zengeya *et al*., 2013)**.

On the contrary, survival rate was higher in SF than in LNF (97.5, 96.75, respectively). This may be due to the challenges facing LNF to adapt with the new spatial environment in SFF, which is characterized by lower temperature and low space in captivity compared to its' endemic habitats in Lake Nasser **(El-Sayed & Fitzsimmons, 2023)**. However, the mortalities were in normal or less than the normal expected levels of mortality.

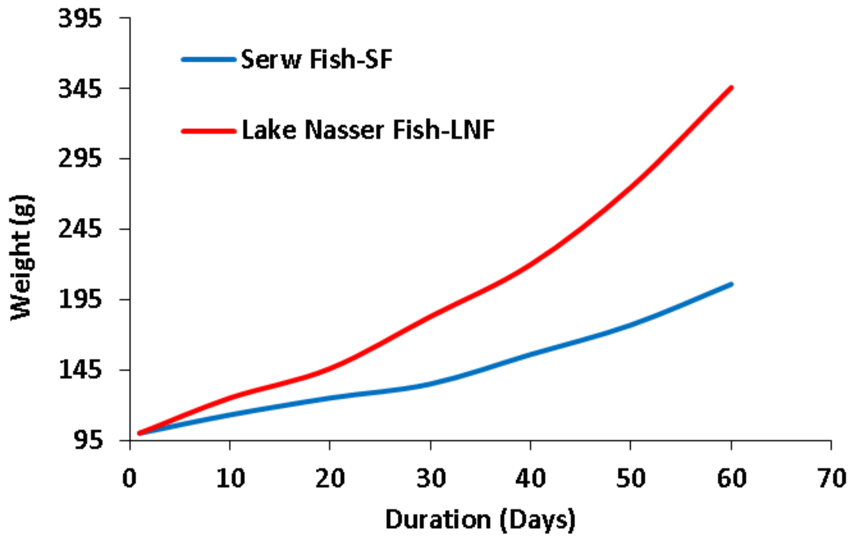

Fig. 1. Growth rates of Lake Nasser fish and Serw fish during the experimental period

By the end of the first experiment, most fish from both strains were sexually mature. According to the measured reproductive parameters, LNF showed higher reproductive and spawning performance than SF, as presented in Table (3).

Table 3. Reproductive efficiency parameters of the Nile tilapia (Avg ± SD) from the Serw Fish Research Station and Lake Nasser, both were reared under the Serw conditions for 60 days

Group	Serw Fish					Lake Nasser Fish				
Parameter	Avg	±	SD	Min	Max	Avg	±	SD	Min	Max
AF (%)	519.0	±	250.1	238.0	816.0	1082.5	±	499.5**	720.0	1800.0
RFL	22.89	±	11.89	11.33	34.00	42.66	±	20.17**	26.66	72.00
RFW	2.53	±	1.05	1.41	3.34	3.20	±	1.67	1.97	5.68
Ova D (mm)	1.06	±	0.26	0.70	1.50	1.38	±	0.33*	0.80	1.80
GSI (%)	2.29	±	0.74	1.66	3.09	3.63	±	1.80**	2.46	6.31
HSI (%)	1.25	±	0.14	1.09	1.39	1.27	±	0.23	1.04	1.58

Values with one asterisk (*) are statistically significant at $P \leq 0.05$.

Values with two asterisks (**) are statistically highly significant at $P \leq 0.05$.

AF: Absolute fecundity**, RFL:** Relative fecundity to length**, RFW:** Relative fecundity to weight, **Ova D:** Ova diameter**, GSI:** Gonado-somatic index**, HSI:** Hepato-somatic index.

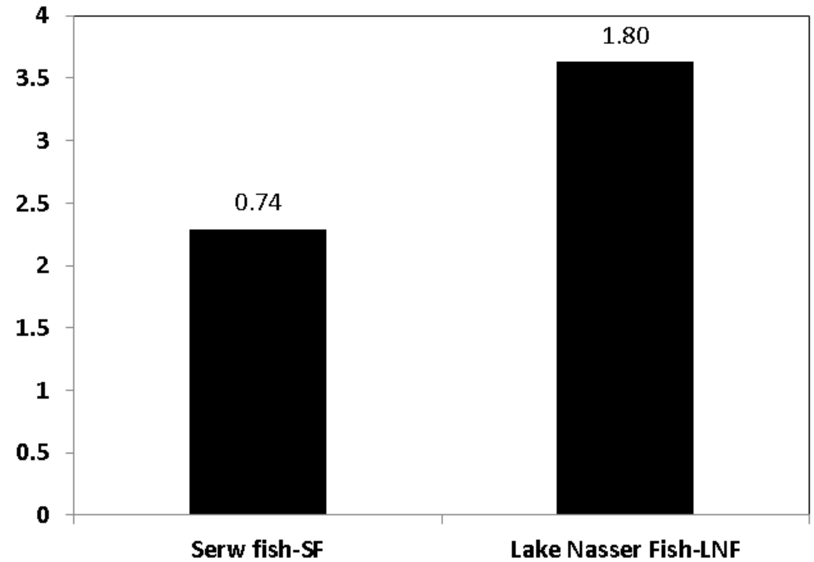

Fig. 2. Gonado-Somatic index (GSI) of Serw fish-SF and Lake Nasser Fish-LNF (Avg±SD)

At the end of the first experiment, the GSI of LNF reached 3.63%, whereas it was only 2.29% in SF (Fig. 2). Similarly, the ova diameter in LNF was much larger than in SF (1.38 mm vs. 1.06 mm, respectively). The absolute fecundity and relative fecundity to length (RFL) in LNF were nearly double those of SF. LNF ovaries contained a higher number of eggs compared to SF. Moreover, the relative fecundity to length in LNF was approximately double that detected in SF (42.66 vs. 22.89, respectively). The number of eggs produced is typical for Nile tilapia, but it also depends on factors such as fish age, size, broodstock genetic origin, environmental conditions, food availability, and husbandry practices **(Tyler & Sumpter, 1996)**. The differences in HSI values between LNF and SF were nearly identical, which may be explained by the well-known feeding cessation during the spawning of the Nile tilapia. This may also account for the high somatic growth observed during periods of low reproductive activity in tilapia **(El-Sayed & Kawanna, 2007)**.

CONCLUSION

In conclusion, the present study reveals that the Nile tilapia inhabiting Lake Nasser has good characteristics compared to those inhabiting the northern Delta without broodstock exchange. The growth factors and reproductive efficiency were much better in Lake Nasser tilapia than in the northern Delta. Therefore, we recommend partial exchange of the broodstock in the northern tilapia farms and hatcheries with the Lake Nasser tilapia to improve the aquaculture sector. Additionally, further studies are needed to investigate the effect of the hybridization between Lake Nasser tilapia and northern Delta tilapia on the produced fish at different age stages.

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Conflict of interest

The authors declare that there is no conflict of interest in the present study.

REFERENCES

Abdel-Hady, M. M.; El-karashily, A. F.; Salem, A. M. and Haggag, S. M. (2024). Sustainable fish production in Egypt: Towards strategic management for capture-based aquaculture. Aquacult. Int., pp.1-26.

Abd El-Hack, M. E.; El-Saadony, M. T.; Nader, M. M.; Salem, H. M; El-Tahan, A. M.; Soliman, S. M. and Khafaga A. F. (2022). Effect of environmental factors on growth performance of Nile tilapia (*Oreochromis niloticus*). Int. J. Biometeor., 66(11): 2183-2194.

Abd Ellah, R. G. (2020). Physical properties of inland lakes and their interaction with global warming: A case study of Lake Nasser, Egypt. Egypt. J. Aquat. Res., 46(2): 103-115.

Abd Ellah, R. G. and El-Geziry T. (2016). Bathymetric study of some khors in Lake Nasser, Egypt. Lak. Reserv. Ponds., 10(2): 139-158.

Addo, S.; Oblie, E. N. A.; Duodu, C. P.; Amponsah, S. K. K.; Sowah, W. and Asamoah, E. K. (2023). Effects of broodstock sex pairing ratios and rest periods of the Nile tilapia *Oreochromis niloticus* on fry production. Ghana J. Sci., 64(2): 1-11.

Ali, F. S.; Nazmi H. M.; Abdelaty B. S.; El-Far, A. M. and Goda A. M. A. S. (2017). Genetic improvement of farmed Nile tilapia (*Oreochromis niloticus*) through selective breeding in Egypt. Int. J. Fish. Aquat. Stud., 5(6): 395-401.

Aly, W. and Abouelfadl K. Y. (2020). Impact of low-level water pollution on some biological aspects of redbelly tilapia (Coptodon zillii) in River Nile, Egypt. Egypt. J. Aquat. Res., 46(3): 273-279.

APHA (American Public Health Association). (2005). Standard Methods for the examination of water and wastewater 21th Ed. APHA, Inc. New York.

Charo-Karisa, H.; Komen, H.; Rezk , M. A.; Ponzoni, R. W.; van Arendonk, J. A. and Bovenhuis H. (2006). Heritability estimates and response to selection for growth of Nile tilapia (*Oreochromis niloticus*) in low-input earthen ponds. Aquacult., 261(2): 479-486.

Eknath, A. E. and Hulata, G. (2009). Use and exchange of genetic resources of Nile tilapia (*Oreochromis niloticus*). Rev. Aquacult., 1(3-4): 197-213.

El Gamal, T. and Zaki, N. (2017). Egyptian irrigation after the Aswan high dam. Irrigated Agriculture in Egypt: Past, Present and Future. 47-79.

El Sayed, A-F.M. (2008). Tilapia feed and feeding in semi-intensive culture systems. In: "Proceedings of the ISTA 8 (8th International Symposium on Tilapia in Aquaculture)". Pp. 717-723.

El-Mezayen, M.M.; Farag, Z.S. and Areda, H.A. (2024). Effect of Aquaculture Conditions on the African Catfish *Clarias Gariepinus* Growth Performance, Hematological, Biochemical, and Histological Parameters. Egypt. J. Aquat. Res., 28(6): 1399-1423.

El-Otify, A. M. (2015). Evaluation of the physicochemical and chlorophyll-a conditions of a subtropical aquaculture in Lake Nasser area, Egypt. Beni-Suef Univ. J. Bas. App. Sci., 4(4): 327-337.

El-Sayed, A. F. M. and Fitzsimmons, K. (2023). From Africa to the world—The journey of Nile tilapia. Rev. Aquacult., (15): 6-21.

El-Sayed, A-FM. (2020). Environmental Requirements. In: "El-Sayed A-FM, ed. Tilapia Culture". 2nd Ed. Elsevier/Academic Press. pp. 47-67.

Entz, B. (1976). Lake Nasser and Lake Nubia. In: "The Nile, biology of an ancient river. Dordrecht". Spring. Nether., pp. 271-298.

FAO (2024). The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action. Rome.

Fulton, T. W. (1904). The rate of growth of fishes. Twenty-second annual report. pp. 141-241.

GAFRD (2018). Fisheries Statistics Yearbook; General Authority for Fish Resources Development: Cairo, Egypt.

Goher, M. E.; Napiórkowska-Krzebietke, A.; Aly, W.; El-Sayed, S. M.; Tahoun, U. M.; Fetouh, M. A.; Hegab, M. H.; Haroon, A. M.; Sabae, S. A.; Abdel-Aal, E. I.; Nassif, M. G. and Hussian, A. E. M. (2021). Comprehensive Insight into Lake Nasser Environment: Water Quality and Biotic Communities—A Case Study before Operating the Renaissance Dam. Water., 13(16): 2195.

Goher, M.E.S.; Farhat, H.; Abdo, M.H. and Salem S.G. (2014). Metal pollution assessment in the surface sediment of Lake Nasser, Egypt. Egypt. J. Aquat. Res., (40): 213–224.

Imam, N.; El-Sayed, S.M. and Goher, M.E.-S. (2020). Risk assessments and spatial distributions of natural radioactivity and heavy metals in Nasser Lake, Egypt. Environ. Sci. Poll. Res., (27): 25475–25493.

Ismail, R. F.; Assem, S. S.; Fahmy, A. F.; Abou Shabana, N. M.; El-Sayed, H. S. and Al-Absawey, M. A. (2016). Reproductive biology, steroid and biochemical profiles of Dentex dentex ovaries in the Eastern Mediterranean in relation to histological structure. Egypt. J. Aquat. Res., 42(2): 149-160.

Kaiser, H.; Brill, G.; Cahill, J.; Collett, P.; Czypionka, K.; Green, A. and Yearsley, R. (2006). Testing clove oil as an anaesthetic for long-distance transport of live fish: the case of the Lake Victoria cichlid *Haplochromis obliquidens*. J. Appl. Ichthyol., 22(6): 510-514.

Mehanna, S. F;, Osman, Y.; El-Mahdy, S. M.; Mohammad, A. S. and Makkey, A. F. (2021). Maximum sustainable yield estimates from Lake Nasser fisheries, Egypt with special reference to Nile Tilapia *Oreochromis niloticus* using ASPIC software. Asia. J. Fish. Aquat. Res., 46-59.

Nasr-Allah, A.M.; Habib, O.A.; Dickson, M. and Dickson, C. (2016). Value Chain Analysis of Lake Nasser Fisheries in Aswan, Upper Egypt; Program Report: 2016-11; World Fish Center: Penang, Malaysia,.. Bishai, H.; Abdel Malek, S.; Khalil, M. Lake Nasser. Egyptian Environmental.

Pullin, R.S.; Eknath, A.E.; Gjedrem, T., Tayamen, M.M.; Macaranas J.M. and Abella, T.A. (1991). The genetic improvement of farmed tilapias (GIFT) project: The story so far. Naga, The ICLARM Quarterly., 14(2): 3-6.

Ridha, M. T. and Cruz E. M. (2000). Effect of light intensity and photoperiod on Nile tilapia *Oreochromis niloticus* L. seed production. Aquacul. Res., 31(7): 609-617.

Rossignoli, C. M.; Manyise, T.; Shikuku, K. M.; Nasr-Allah, A. M.; Dompreh, E. B.; Henriksson, P. J. and Gasparatos A. (2023). Tilapia aquaculture systems in Egypt: Characteristics, sustainability outcomes and entry points for sustainable aquatic food systems. Aquacult., (577): 739952.

Salem, T.A. and Mageed A.A.A. (2021). Assessment of the Impact of the Nile Flood on Food Chain in Lake Nasser—Egypt, with Special Reference to Turbidity. Open. J. Ecol., (11): 41-51.

Salih, S. Q.; Allawi, M. F.; Yousif, A. A.; Armanuos, A. M.; Saggi, M. K.; Ali, M. and Chau, K. W. (2019). Viability of the advanced adaptive neuro-fuzzy inference system model on reservoir evaporation process simulation: case study of Nasser Lake in Egypt. Engin. Applic. Computat. Flu. Mech., 13(1): 878-891.

Shalloof, K. A. S.; Alaa, M. and Aly, W. (2020). Feeding habits and trophic levels of cichlid species in tropical reservoir, Lake Nasser, Egypt. Egypt. J. Aquat. Res., 46(2): 159-165.

Tyler, C. R. and Sumpter, J. P. (1996). Oocyte growth and development in teleosts. Rev. Fish. Boil. fisher., (6): 287-318.

Zwieten, P. A.; Béné, C.; Kolding, J.; Brummett, R. and Valbo-Jorgensen, J. (2011). Review of tropical reservoirs and their fisheries: The cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoir (No. 557). Food and Agriculture Organization of the United Nations (FAO), Rome.

Watanabe, W. O.; Fitzsimmons, K. and Yi, Y. (2024). Farming tilapia in saline waters. Tilapia, pp. 347-447.

YEAG (Youth Employment in Aswan Governorate Project). (2017). Report of Fisheries Assessment of Lake Nasser, Aswan–Egypt; World Fish Center: Penang, Malaysia.

Yue, G. H.; Ma, K. Y. and Xia, J. H. (2024). Status of conventional and molecular breeding of salinity-tolerant tilapia. Rev. Aquacult., 16(1): 271-286.

Zengeya, T.A.; Robertson, M.P.; Booth, A.J. and Chimimba, **C.T.** (2013). A qualitative ecological risk assessment of the invasive Nile tilapia, Oreochromis niloticus in a sub-tropical African river system (Limpopo River, South Africa). Aquat. Conserv. Mar. Fresh. Ecosys., 23(1): 51-64.

Zulfahmi, I.; Muliari, M.; Akmal, Y. and Batubara, A.S. (2018) Reproductive performance and gonad histopathology of female Nile tilapia (*Oreochromis niloticus* Linnaeus 1758) exposed to palm oil effluent. Egypt. J. Aquat. Res., 44(4): 327–332.