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Age and Growth of the Freshwater Pufferfish *Tetraodon lineatus* Linnaeus 1758 from Lake Nasser, Egypt

Asmaa A. A. Ahmed[1], Walid Aly[2,] *, Alaa Younis[3,4], Khaled Y. AbouelFadl[5]

[1]Fisheries Department, Faculty of Fish Resources, Suez University, Suez 43518, Egypt
[2]Fisheries Biology Lab, Fisheries Division, National Institute of Oceanography and Fisheries (NIOF), Egypt
[3]Department of Chemistry, College of Science, Qassim University, Buraidah 51452, Saudi Arabia
[4]Aquatic Environment Department, Faculty of Fish Resources, Suez University, Suez 43518, Egypt
[5]Faculty of Fish and Fisheries Technology, Aswan University, Egypt
***Corresponding author: walid.soton@gmail.com**

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ABSTRACT

The growth parameters of the freshwater puffer fish *Tetraodon lineatus* from Lake Nasser, Egypt were estimated for the first time. A total of 2691 samples were monthly collected from commercial fishing boats at landing sites along the lake from October 2017 to September 2018. The total length of the samples ranged from 13.8 to 50.0cm, with an average of 24.71cm, and the total weight ranged from 63.7 to 2827.1g, with an average of 374.65 g. The length-weight relationship revealed a negative allometric growth for males, females, and combined sexes, with an insignificant difference between males and females at ($P > 0.05$). The maximum monthly condition factor was recorded in March for males (2.13) and in January for both females (2.07) and combined sexes (2.22). The age of 533 samples was determined by using annual rings of their vertebrae. The results showed that three samples had the highest age (8 years), while 16 samples had the smallest age (0 years). The estimated asymptotic length of the investigated species was 57.2 cm; the growth coefficient (instantaneous rate) (K) was 0.143 $year^{-1}$; t_o was -1.89 year; the growth performance index (Ø) was 2.67, and longevity (t_{max}) was 12.02 years. The results of this study are among the first of their kind in the biological data on the freshwater pufferfish in Lake Nasser. The findings of the current study add more insight into the *T. lineatus* age and growth model which would help in establishing management plans for Lake Nasser fisheries.

INTRODUCTION

The fisheries production of Lake Nasser is an important source of food for the upper Egypt region (**Shalloof *et al.*, 2020**). The lake production includes economically important fish species e.g., tilapia species, the Nile perch (*Lates niloticus*), *Alestes* spp., and *Hydrocynus* spp. (**Goher *et al.*, 2021**). The freshwater pufferfish *Tetraodon lineatus* is considered a discarded catch in Lake Nasser as pufferfishes, in general, are prohibited by the Egyptian law neither for fishing nor trading due to their toxicity as food (**Farrag *et***

***al.*, 2022)**. Consequently, the population of the pufferfish has increased recently causing losses to entangled fish and damage to the fishing gears (**Farrag *et al.*, 2016)**.

Tetraodon lineatus belongs to the family Tetraodontidae which is a group of primarily marine and estuarine fish of the order Tetraodontiformes. The family includes many familiar species, which are variously called pufferfish, toadfish and sea squab (**Amedei & Niccolai, 2014**). They are morphologically similar to the closely related porcupine fish (family Diodontidae), which have large external spines (unlike the thinner, hidden spines of the Tetraodontidae **(Matsuura, 2015**). Tetraodontidae species are found in warm and temperate waters around the world. They generally inhabit shallow coastal waters and coral reefs. They can be found in both freshwater and marine environments (**McEachran & Fechhelm, 2021**). Most species are toxic and some are among the most poisonous vertebrates in the world. (**Farrag *et al.*, 2022)**.

Tetraodontidae species range in size from about 7cm to over 75cm. They have four large teeth that are fused into an upper and lower plate; this gives them their name ("tetra" meaning four and "odont" meaning teeth), and the body is typically spiny with short fins (**Farrag, 2022**). Most tetraodontids feed on molluscs such as clams or oysters; some also feed on crustaceans or small fish. Some species use their fused teeth to crush shells or coral for food (**Suvarna & Sivan, 2017**).

Growth is a continuous additive process that incorporates two opposing eco-physiological processes, anabolism and catabolism, over a descriptive time interval (**von Bertalanffy, 1938**). Accurate estimates of growth parameters, associated with the descriptive changes in the time-specific length or weight of a fish, are essential for monitoring many aspects of fish population status, such as stock age structure, age-at-50% maturity, yield per-recruit, exploitation, productivity (**Simon & Mazlan, 2008; Zhou *et al.*, 2017**). In addition to theafore- mentioned aspects, assessing fisheries regulations and management options (**Quinn & Deriso, 1999; Zhu *et al.*, 2016**) are of concern. It is essential to understand the age, growth and condition of fish for the maximum utilization and successful management of fishery resources (**Gaygusuz, 2018**). Numerous studies have been made on the growth parameters of the freshwater fishes of Egypt, particularly the most common and commercial species (**Harabawy, 1993; Mekkawy, 1998; Bishai *et al.*, 2000; Khalifa *et al.*, 2000; Adam, 2004; EL-Haweet *et al.*, 2008; Ragheb, 2014; Shalloof & El-Far, 2017**). Exploring the age and growth characteristics of fish populations is essential for supplying basic information for formulating conservation policies aiming to exploit these renewable resources. The determination of fish growth parameters contributes to the estimation of growth rates and the determination age structure of the population (**Campana, 2001; Neilson & Campana, 2008**). The information on population dynamics is important to estimate the amount of caught fish for resources management programs (**Santos *et al.*, 2017**).

Biological and population dynamics data are required for all species, even if they were undesirable or toxic as pufferfish to understand their behavior (**AbouelFadl & Farrag,**

2021). Therefore, this study was carried out to provide the needed information on the biology and population dynamics of *T. lineatus* in Nasser Lake, Egypt.

MATERIALS AND METHODS

A total of 2691 specimens of *T. lineatus* were monthly collected from Lake Nasser, Aswan, Egypt (Fig. 1) during the period from October 2017 to September 2018. Trammel nets were the main fishing gear that accidentally caught this fish species. Samples were collected from commercial fishing boats at different landing sites along the lake from Aswan City in the north to Abu Simbel in the south. Samples were transported on ice to the laboratories of the National Institute of Oceanography and Fisheries (NIOF) research station at Aswan City to be investigated.

The total length (TL) of each sample was measured to the nearest 0.1cm using standard rulers. The total and gutted weights were measured to the nearest 0.1g using an electronic lab scale. Moreover, the sex of each sample was determined, and the data were sorted as males, females and combined sexes (including males, females and non-sexed specimens).

The length–weight relationship was calculated as $W = a * L^b$ (**Le Cren 1951**), where W is the total weight in grams (g); L is the total length in cm; *a* is the intercept, and *b* is the slope of the trending line. The condition factor ($K = 100 * W_{gut}\backslash L^3$) of the fish was calculated according to **Bagenal and Tesch (1978)**, where W_{gut} is the gutted weight in grams (g), and L is the total length in cm.

A total of 533 subsamples were selected to represent all the length groups available in the original samples, and they were used in the ageing procedure. Since the pufferfish have no scales and irregular semi-soft otolith (**Farrag *et al.*, 2016**), age was determined by reading the samples' vertebrae (Fig. 2). Vertebra of the specimens was carefully removed, cleaned by ammonia (20%) concentration, dried, cut and examined on a dark background with reflected light using a binocular microscope. Age was determined by counting the opaque rings on the vertebral centrum. The growth parameters of von Bertalanffy, asymptotic length (L_∞), and the growth coefficient (instantaneous rate) (K) were estimated according to **Ford (1933)** and **Walford (1946)**. Growth performance (Ø = Log k + 2Log L_∞; (**Pauly & Munro, 1984)**) and the potential longevity of age ($t_{max} = 3/k + t_o$; (**Pauly, 1983**)) were estimated, where $t_o = -a/b$. The presented data were analyzed statistically using Microsoft Excel (2013).

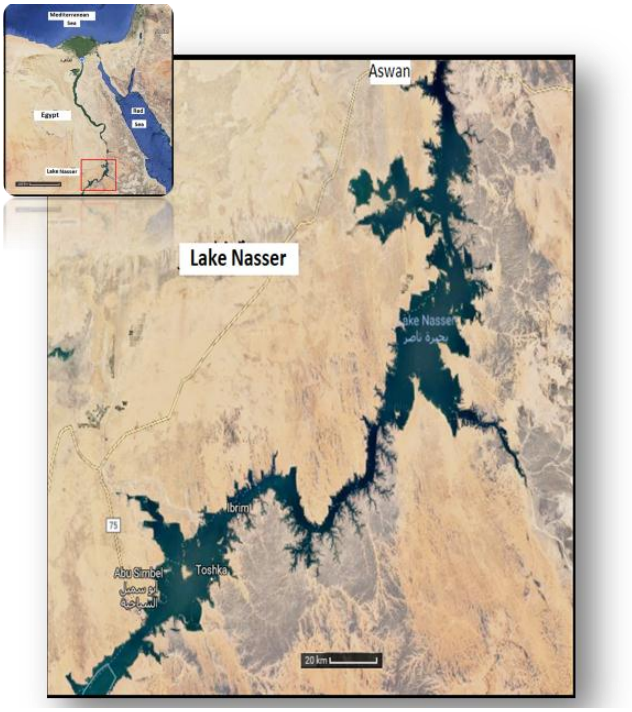

Fig. 1. A map for upper Egypt showing the location of the study area (Lake Nasser) and its main morphology

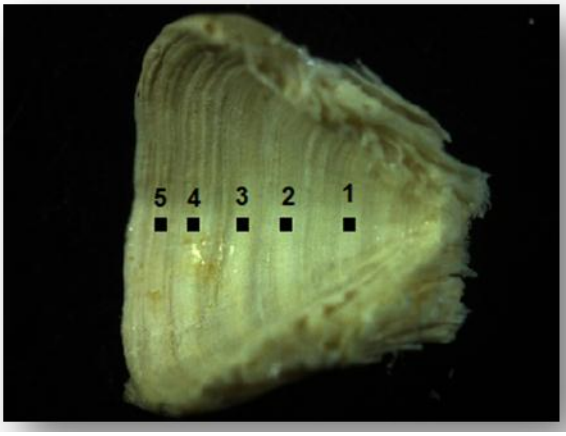

Fig. 2. Vertebra of the freshwater pufferfish *T. lineatus* from lake Nasser, Egypt, showing five opaque rings (age group V)

RESULTS AND DISCUSSION

Length-weight relationship (LWR)

The LWR in fish is an important biological parameter that, in conjunction with environmental and population parameters, presents useful information for fisheries

management and the conservation of natural populations (**Kimmerer *et al.*, 2005; Froese, 2006; Simon & Mazlan, 2008; Karuppiah *et al.*, 2021; Abdellatif *et al*., 2022**).

The length–weight relationship of *T. lineatus* was studied by using the 2691 specimens (985 males, 1675 females and 31 unsexed) (Fig. 3). The total length of all samples ranged between 13.8 to 50.0cm, with an average of 24.71cm, while the total weight ranged from 63.7 to 2827.1g, with an average of 374.7g, and the gutted weight ranged from 56.0 to 2500.6g, with an average of 334.3g. The length-weight relationship equations are presented as follows:

$W_t = 0.065\ L^{2.66}$ r = 0.887 Males

$W_t = 0.053\ L^{2.72}$ r = 0.885 Females

$W_t = 0.056\ L^{2.70}$ r = 0.894 All specimens (Combined sexes)

Where, W_t is the total weight, and L is the total length.

The length range of *T. lineatus* samples from Lake Nasser is wider than that obtained for the same species in the Nile by **Ali *et al.* (2014)**, who reported a length range of 21–41 cm, and that reported by **AbouelFadl and Farrag (2021**) also for the same species in the Nile, who reported a length range of 13.5 –38.5cm. The difference may be due to variations in the number of samples, duration of specimen collection and the difference in the environment of the Nile River and Lake Nasser.

The exponent "*b*" of the LWR calculated during the current study was "2.70" which is less than the "3" model value, reflecting a negative allometric growth. This kind of growth was also reported for the same species and other marine pufferfish (**Farrag *et al.*, 2015, 2016; AbouelFadl & Farrag, 2021**).

Condition factor

The condition factor is a parameter that expresses the interactions between abiotic and biotic factors in fish physiological conditions and the degree of the well-being of stock (**Bagenal & Tesch, 1978)**.

The average condition factor was nearly similar for males (K_m), females (K_f) and combined sexes (K_c) (2.08, 1.99, and 2.03, respectively) (Table 1). The maximum condition factor was recorded in March for males (2.13), and in January for both females (2.07) and combined sexes (2.22) (Fig. 4).

The values of the condition factor were slightly less than "3", which reflects that the fish were well adpted with the environmental conditions of the lake. (**Le Cren, 1951; Lagler, 1956**).

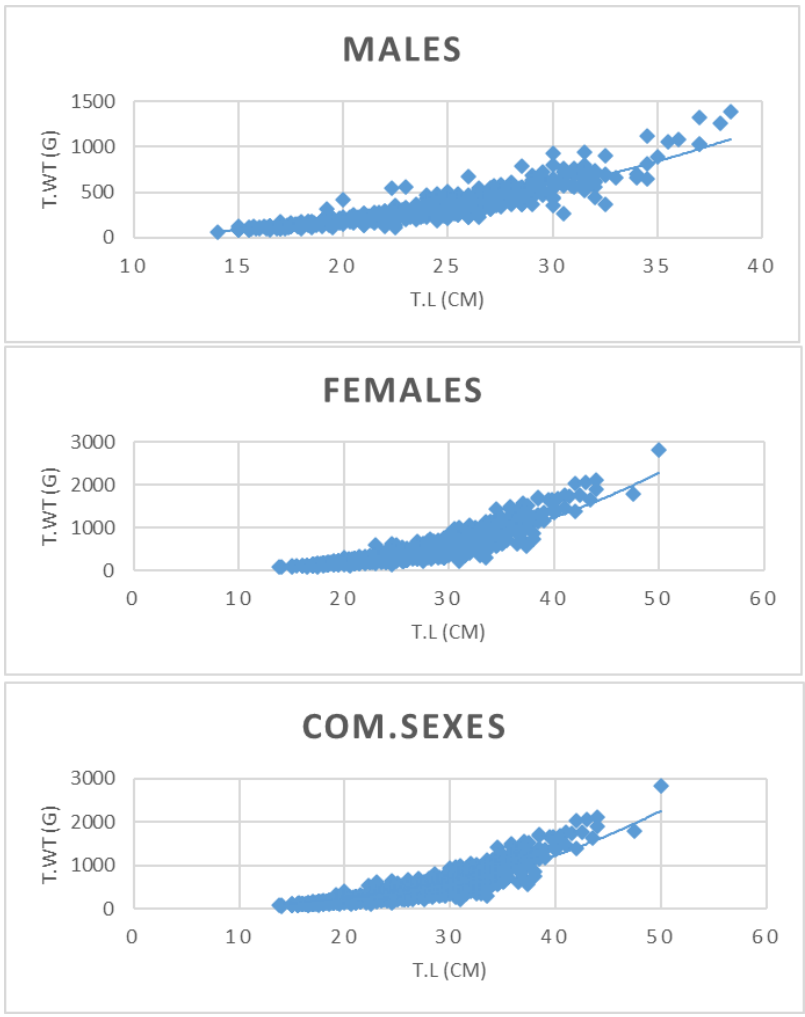

Fig. 3. The length–weight relationship for males, females and combined sexes of *T. Lineatus* from Lake Nasser, Egypt during 2017-2018

Age composition

The life history of *T. lineatus* was investigated, and nine age groups were distinguished (Fig. 5). The mean lengths for the reported age groups were 15.1, 19.90, 25.04, 29.70, 34.26, 37.18, 39.86, 41.78 and 45.00cm. The mean weights were calculated as 95.1, 194.08, 340.36, 555.86, 883.63, 1175.93, 1579.32, 1669.66 and 1854.5g (Tables 2, 3).

Age composition revealed that age group I was the most abundant (31.52%), followed by age group III (26.62%), while the least abundant age group was group VIII (0.06%) (Fig.6). Growth in length (increment) gave the highest rate at the age group I, while minimum growth was recorded in the age group VIII (Fig. 7).

Table 1. The average condition factors for males (K_m), females (K_f) and combined sexes (K_c) of *T. Lineatus* from Lake Nasser, Egypt during 2017-2018

Month	K_c	K_f	K_m
Oct. 2017	1.97	2.00	2.09
Nov. 2017	2.13	1.97	2.13
Dec. 2017	2.11	1.94	1.93
Jan. 2018	2.22	2.07	2.10
Fab. 2018	2.13	1.99	2.05
Mar. 2018	2.17	2.04	2.13
Apr.2018	1.92	1.93	2.03
May. 2018	1.99	1.98	2.04
Jun. 2018	2.04	2.05	2.12
Jul. 2018	1.92	2.04	2.07
Aug. 2018	1.83	2.04	2.05
Sep. 2018	1.95	1.84	2.03
Total average	2.03	1.99	2.08

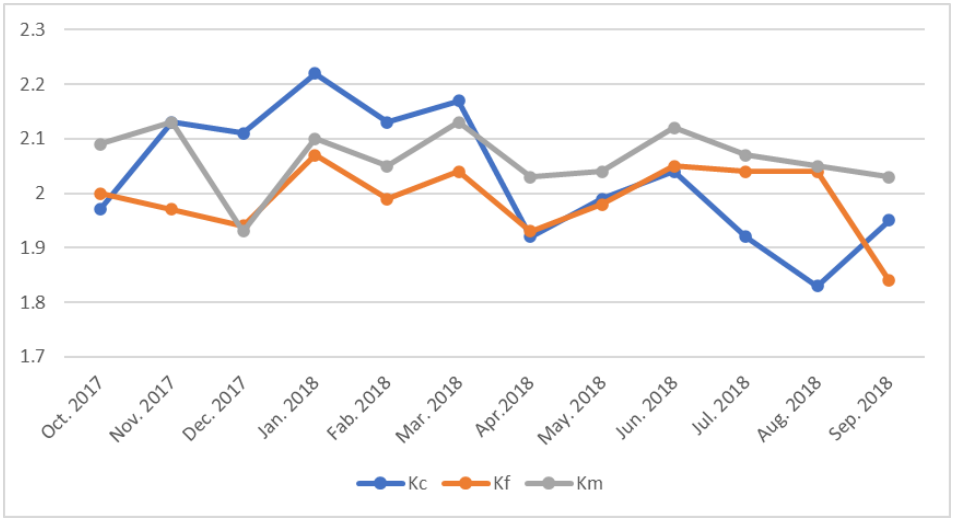

Fig. 4. The monthly variation trend of the average condition factors for males (K_m), females (K_f) and combined sexes (K_c) of *T. Lineatus* from Lake Nasser, Egypt during 2017-2018

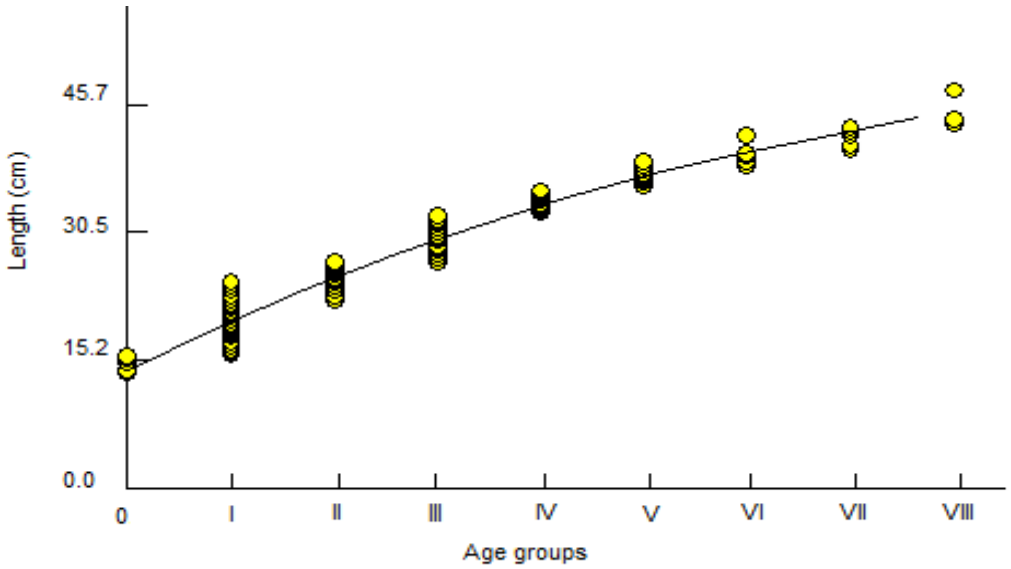

Fig. 5. Growth curve estimated from length-at-age (b) of *T. lineatus* from Lake Nasser, Egypt

Table 2. The average length at age groups for combined sexes of *T. Lineatus* Egypt, Lake Nasser during 2017-2018

Age groups	No.	Average TL (cm)	Min. TL (cm)	Max. TL (cm)
0	16	15.1	13.8	15.8
1	168	19.9	16	24.5
2	107	25.0	22.5	27
3	141	29.7	27	32.5
4	55	34.3	33	35.5
5	33	37.2	36	39
6	5	39.9	38.5	42
7	5	41.8	40.4	43
8	3	45.0	43.5	47.5
Total	**533**	**26.5**	**13.8**	**47.5**

Table 3. The average weight at age groups for combined sexes of *T. lineatus* Egypt, Lake Nasser during 2017-2018

Age groups	No.	Average T.wt.(g)	Min. T.wt. (g)	Max. T.wt. (g)
0	16	95.1	63.7	126.7
1	168	194.1	90.6	382.1
2	107	340.4	196.3	608.8
3	141	555.9	208.5	992.5
4	55	883.6	348.5	1423.5
5	33	1175.9	740.5	1559
6	5	1579.3	1179.5	2025
7	5	1669.7	1395.3	2059
8	3	1854.5	1641	2120.6
Total	**533**	**484.3**	**63.7**	**2120.6**

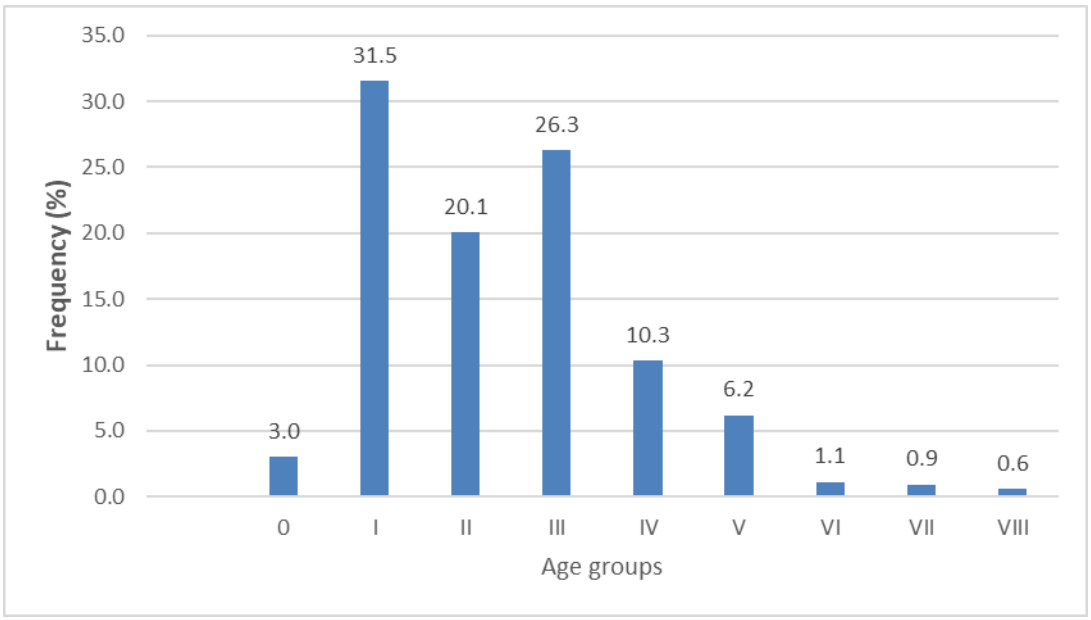

Fig. 6. Age composition of *T. lineatus* samples from Lake Nasser, Egypt

The lifespan calculated for *T. lineatus* in the current study (8 years) was greater than that reported in the River Nile (five years) obtained by **AbouelFadl and Farrag (2021)** for the same species. This reflects that this species is well adapted in the habitats of Lake Nasser than that of the Nile. Moreover, this species has no economic importance for Lake Nasser fisheries which leads to the absence of any pressure from the fishing activities.

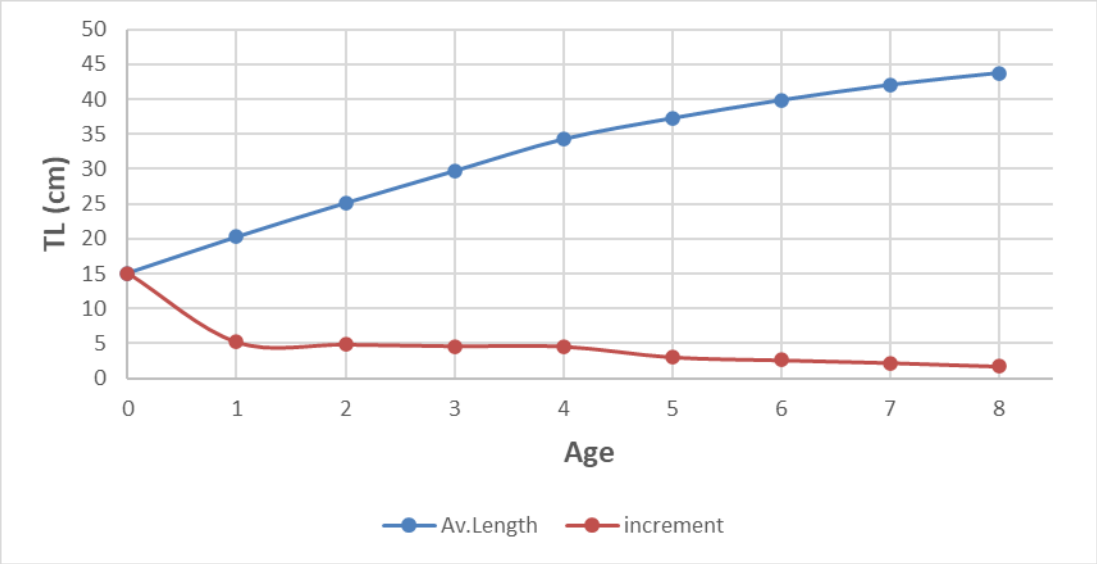

Fig. 7. Growth curve in lengths and annual increment of *T. lineatus* samples from Lake Nasser, Egypt

The growth parameters

The growth model parameters are important for the management and assessment of the fish stock. The growth model parameters were calculated during the current study as L_{∞} = 57.222 cm, K = 0.143 year^{-1},
t_o = -1.89 year^{-1}. In addition, Ø was 2.67; the t_{max} was 12.02 years, and the W_{∞} was 3116.1 g.

The results showed that L_{∞} , W_{∞} and t_{max} had higher values than those reported for the same species in the River Nile in the study of **AbouelFadl and Farrag (2021)**, while **Φ**, $t_{0,}$ and K had lower values than those reported in the same study. These differences may be due to the variance in the environmental characteristics between the Nile River and Lake Nasser. Table (4) shows a comparison between the growth parameters of *T. lineatus* described in the current study and that reported for the same species and similar family members in literature.

Table 4. Condition factor (Kc), length–weight relationship equations, von Bertalanffy growth parameters (K, L_∞, and t_0), growth performance index (Φ), and longevity (t_{max}) of (Family: *Tetraodontidae*) from various regions by various authors

Species	region	sex	Length-weight relationship	R^2	kc	Growth parameters					Author
						k	t_0	L_∞	Φ	t_{max}	
Lagocephalus sceleratus	Turkey's Mediterranean coast	M	$W=0.012L^{2.97}$	0.994	1.14	0.099	-0.43	126	3.19	---	Aydin (2011)
		F	$W=0.011L^{2.98}$	0.994	1.13						
		C	$W=0.012L^{2.97}$	0.995	1.14						
Lagocephalus sceleratus	Egyptian Mediterranean coast	M	$W=0.012L^{2.95}$	0.984	0.97	0.18	0.11	101.6	3.28	16.1	Farrag (2014)
		F	$W=0.013L^{2.93}$	0.997							
		C	$W=0.013L^{2.93}$	0.996							
Tetraodon lineatus	The Nile	M	$W=0.038L^{2.88}$	0.915	2.78	0.24	-0.60	46.2	2.71	11.7	AbouelFadl & Farrag (2021)
		F	$W=0.061L^{2.73}$	0.899							
		C	$W=0.050L^{2.79}$	0.910							
Tetraodon lineatus	Lake Nasser	M	$W=0.064L^{2.66}$	0.887	2.02	0.14	-1.89	57.2	2.67	12.02	The present study
		F	$W=0.052L^{2.72}$	0.880							
		C	$W=0.056L^{2.70}$	0.894							

CONCLUSION

The freshwater puffer fish *Tetraodon lineatus* is a discarded catch in Lake Nasser, which has increased recently causing losses to entangled fishes and damage to the fishing gears. This study is one of the limited studies on *T. lineatus* in Egypt, particularly in the fields of population dynamics. Population dynamics data are required for this species to understand its growth behavior. The current study reported a wider length range than that previously reported for the same species in a different freshwater environment and other species belonging to the same family in marine environments. The LWR data of the investigated species reflected a negative allometric growth, which is also reported for other marine and freshwater pufferfish. The condition factor results reflected that *T. lineatus* were in a good condition in Lake Nasser, and its monthly variation trend did not follow a definite pattern. The life history of *T. lineatus* was investigated and nine age groups were distinguished in the Lake Nasser population. The comparison of the growth parameters of *T. lineatus* described in the current study and that reported for the same species and similar family members in the literature indicated that the growth pattern of the investigated species in Lake Nasser is analogous to that described in those studies. The findings of the current study add more insight into the *T. lineatus* age and growth model, which would help in establishing management plans for Lake Nasser fisheries.

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