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POPULATION DYNAMICS OF THE INDIAN KILLIFISH *APLOCHEILUS LINEATUS* (VALENCIENNES) FROM THE RIVER TAMBARAPARANI, TIRUNELVELI. (CYPRINODONTIFORMES, APLOCHEILIDAE)

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ABSTRACT
Total and standard length of male and female varied between 35 - 75mm, 30 - 70mm and 28 - 65mm, 26 - 62mm respectively. The body weight ranged from 0.65 - 2.63g for male and 0.73 - 2.25g for female. The male and female ratio did not differ significantly from the expected 1:1 ratio. Male/female sex ratio varied with season. On the whole number of females in the population was high in all the months of the study period, but their numbers were more especially during the peak breeding months. Male *A. lineatus* was 0 - 6 age and female were 0 - 5 in general. Back calculated length at the time of first annulus formation was 40 - 43mmTL for males and 42 - 48mmTL for females. Growth of *A. lineatus* female was most rapid during the first and second year and remained constant thereafter whereas males showed slower growth rate at the first and second year and rapid growth thereafter. Initially females were larger in size males dominate in the later life. Total instantaneous mortality for the males was 1.326/year and for all females 1.208/year. The Fishing mortality coefficient was 0.406/year for males and 0.158/year for females.

KEYWORDS: Killifish, growth, *Aplocheilus lineatus*, von Bertanloffy equation, mortality.

INTRODUCTION
Population dynamics is the study of the changes in the number and composition of individuals in a population, and the factors that influence those changes. Population dynamics involves five basic attributes of interest to which all changes in populations can be related: birth, death, sex ratio, age structure, and dispersal. Le Cren (1951) proposed that the length-weight relationship of fish serves two purposes, namely to determine the mathematical relationship between two variables, *i.e.*, length and weight, and to measure the variations from expected weight for length of individuals or group of fishes. Length or weight data combined with age information can be used to construct growth curves. The weight of a fish is a function of length, since length is a linear measure and weight, a measure of volume.

Age and growth characterize the life span of fish, environmental conditions, age of sexual maturity and breeding (Kapakos *et al.*, 2024). Information on growth is important in the selection of fish for aquaculture and in estimating food consumption of fish populations (Kamal *et al.*, 2009). Growth varies with age, sex, season and reproductive cycle. Fishes are aged with reasonable accuracy by a study of their bony structures (scales, otolith sagittae, operculars, *etc*.,). Advances in otolith microstructure analysis and developments in computer-aided length-based age estimation techniques have resulted in a wide use of otoliths and length frequency data in growth studies. Characteristic zones, which appear at regular intervals, during the growth of otolith in fishes, are frequently used as indicators of age (Podrabsky, 2017).

Back-calculation of fish lengths from otoliths or scale annuli is a useful tool for estimating the size of fish at the formation of annulus. Until recently, various studies have used back-calculation models to estimate the past fish length and growth (Nester *et al.*, 2025). There are several ways of modeling the growth of fish (Podrabsky, 2017). However, the von Bertalanffy's Growth Function (VBGF) could be used in the estimation of growth parameters as these parameters could be used as an input data to estimate the mortality parameters and for the estimation of field recruit in fishes using prediction models. This equation serves as an excellent tool in the estimation of growth parameters in fishes *Aphanius fasciatus* (Chaibi *et al.*, 2015), *Fundulus parvipinnis* (Brown *et al.*, 2011), *Cynopoecilus melanotaenia* (Arenzon *et al.*, 2001; Arenzon *et al.*, 2002) and

Nothobranchius furzeri (Podrabsky, 2017). In the present study, attempts were made to study certain population parameters of the killifish *Aplocheilus lineatus.*

MATERIALS AND METHODS

The killifish *A. lineatus* were collected from August 2022 - July 2024 from River Tambarabarani at Tirunelveli (Tamil Nadu), (8.44^o N and 77.44^o E) in different locations to study the intraspecific and the site-specific variations. Total length (TL) and standard length (SL) were measured following Nester *et al.*, (2025) to the nearest millimeter and the live weight to the nearest milligram. The specimens were segregated as immature, mature and maturing depending on their gonadal development and length-weight data and their population size was noted.

Sex Ratio

The sex-ratio of *A. lineatus* was calculated as the percentage occurrence of each sex in the total catch for every month, as well as in three different classes (Class I: 25 - 33mm; Class II: 34 - 42mm; and Class III: 43 - 51mm) (Mazzoni and Caramaschi, 1995). Deviations in sex-ratios from an expected 1:1 ratio were tested using χ^2 goodness of fit (Kamal *et al.*, 2009). Total Instantaneous mortality (Z) was estimated by growth and selection parameters (Beverton and Holt, 1956).

Age and growth

The left sagittae of *A. lineatus* was used for age determination; however in cases where the left otolith was broken, lost or damaged during processing, the right otolith was substituted (Campana and Thorrold, 2001). These otoliths were placed on a clean glass slide on a black field, illuminated with reflected light and examined under a binocular microscope at 50x magnification. The number of opaque zones and their corresponding distance from the otolith core to the dorsal edge of the otolith (Otolith radius) and the distal edge of each opaque band were noted. To determine the accuracy of band counts, each otolith was counted 2 - 3 times, the best of two were taken into account, and their average was calculated. Each otolith section was used for age and growth analysis only if two of three separate readings were the same and if the greatest difference between dissimilar counts was only one.

To estimate the growth rate of *A. lineatus*, the whole length distribution by age class was used. The total length distribution by age class was fitted to the von Bertalanffy equation. This function describes the relationship between the age and the length of a fish. The equation to describe the mean growth of a population of *A. lineatus* was

$$L_t = L_\infty (1- ^{\exp(-k(t-t_o))})$$

Where

L_t is the mean length at age 't'

L_∞ is the asymptotic mean length.

k is the rate at which the curve approaches the asymptote.

t_o is the age at which mean length is zero (Korwin, 2012).

The parameters of the von Bertalanffy growth curve were determined by Marquardt non-linear least-squares regression analysis using SPSS 9.0. Growth parameters were calculated for both sexes.

Back calculation

Data obtained were subjected to back calculation using the following formula (Korwin, 2012):

$$L_n = \frac{A_n - A_n}{C_1 - C_1} \times L$$

Where C_1 - C_1 is the diameter of the otolith, A_n - A_n is the distance between the respective annuli, L is the total length of the fish at the time of capture and L_n is the length at the time of formation of an annulus. Back calculation was used to estimate the size of each fish at the time each annulus was formed (Nester *et al.*, (2025). Relationships of fish length to the otolith radius were determined using least squares regression analysis (Statview) and were compared by analysis of variance (ANCOVA; Sokal and Rohlf, 1981).

Mortality

Mortality is measured as the number of fishes that die per unit time (usually one year or month) divided by the number of fishes alive at the beginning of the time period. Mortality was estimated using the formula (Nester *et al.*, 2025):

$$\text{Total instantaneous mortality (Z)} = K \times \frac{\bar{L}_\infty - L}{L - L'}$$

Natural mortality $\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$

Fishing mortality (F) = Z - M.

Where K is the growth coefficient, L_∞ is the asymptotic length, L is the mean length of fish length L′and longer, L′ is the smallest length of fish that are fully represented in catch samples, and T is the annual mean temperature.

RESULTS

Sex ratio

A microscopic examination of gonads indicated that *A. lineatus* was characterized by a gonochoristic organization. Out of 6623 specimens 2908 (44.24%) were males and 3715 (55.76%) were females. The male and female ratio did not differ significantly ($p < 0.001$) from the expected 1:1 ratio. The male / female sex ratio varied with the period. On the whole the number of females in the population was high in all the months of the study period, but their numbers were more especially during the peak breeding months (October, December, April, June). The number of males was higher only during June and September. When the data were combined for the corresponding months during the study period, the male: female ratio varied from 1 to 1.11:1 to 1.89, respectively.

In general the number of males and females was equal in the length group 35 - 45mmSL whereas the females slightly outnumbered the males in the length groups 46 - 55mmSL and 56 - 65mmSL.

With respect to the seasonal changes in sex ratio inrelation to length, the number of females were remarkably higher in number the than males during the peak breeding period (October, December, April, June). The sex ratio was almost 1:1 in all the length groups for 35 - 45mm, 46 - 55mm, and 56 - 65mmSL were 1:1.12, 1:1.19 and 1:1.16 (Table 38). Even lengthwise, the females slightly dominated in the population. However an overall homogeneity in the distribution of the sexes was evident based on the sex ratio analysis.

Age determination

Age determination was based on sagittae of *A. lineatus* from 750 fishes from Tirunelveli, 652 from Nagercoil and 576 from Authoor. Alternating opaque and hyaline zones, which comprised an annual growth increment, were evident on the killifish otolith. Only 13 were considered unreadable. Agreement between the number of opaque bands counted on whole otoliths and the number counted on the processed otoliths was 98.9%, indicating that the whole otolith can be used reliably to age killifish.

The mean marginal increment data indicated that opaque band formation occurred once in a year for age 1 - 4 fishes. There are no apparent differences between the sexes in the timing and duration of annulus formation within the area (Intraspecific). Male *A. lineatus* was 0 - 6 age and female were 0 - 5 in general. In Tirunelveli, Nagercoil (Madaswamy, 2001) and Authoor the males were recorded at 0 - 6 age. It was observed that the females were bigger than the males at age 1; (*i.e.*,) the males were 43 - 45mmTL and the females 45 - 49mmTL especially when at Lm_{50}. The initial growth was faster in the females than in the males. But when the males attained an age of 3 - 6 years they grew faster than the females and after that the males became larger than the females during adult maturity. The lifespan of *A. lineatus* was observed to be 5 - 6 years as per the record of the annuli in the otoliths.

The mean back calculated length (Table 1) of *A. lineatus* was 40 - 43mmTL at the time of the first annulus formation and 43 - 48mmTL at age 1. In general back-calculated length at the time of the first annulus formation and average observed length at age 1 were significantly different and bigger for females. Differences in average observed length at age 1 or in back calculated lengths at the time of the first annulus formation among sampling areas were evident but not always similar. For example the mean back-calculated length and the average observed length of the females were significantly different among areas ($p < 0.001$), as well as all pair wise comparison between areas ($p < 0.001$). However, the largest back calculated length came from a different sampling area than did the largest average observed length (Tables 2 and 3).

Table 1: *A. lineatus: Comparison* of back calculated and observed mean length (mm) for ages 1-6. Numbers of fish are in parentheses. All mean length were significantly larger for males than females, exception for fish with one annulus.

Annulus or age group	TIRUNELVELI	NAGERCOIL	AUTHOOR
Males : Back-calculated length at annulus formation			
1	43.7 (125)	48.0(118)	45.0 (125)
2	51.8 (132)	49.0(123)	48.5 (131)
3	57.8 (117)	54.3(127)	52.7 (135)
4	60.9 (122)	58.0(118)	57.5 (123)
5	62.9 (115)	60.3(117)	59.3 (115)
6	64.2 (117)	65.0(118)	62.5 (152)
Males : Observed length in age -group			
1	45 (135)	49.0 (182)	47.0 (162)
2	54 (165)	51.0 (145)	52.5 (151)
3	58 (182)	56.0 (125)	57.5 (155)
4	62 (151)	60.0 (113)	59.5 (152)
5	64 (135)	61.5 (142)	62.0 (140)
6	66 (143)	68.0 (151)	64.0 (115)
Females : Back-calculated length at annulus formation			
1	46.8 (125)	47.5 (132)	47.0 (160)
2	53.5 (135)	55.3 (135)	54.5 (150)
3	56.6 (132)	56.5 (135)	56.5 (113)
4	58.1 (115)	59.3 (141)	59.5 (115)
5	58.8 (118)	60.5 (145)	60.2 (113)

6	59.2 (125)	60.5 (152)	61.3 (115)
Females : Observed length in age -group			
1	48 (175)	49.3 (165)	48.7 (165)
2	55 (182)	56.0 (162)	55.7 (132)
3	58 (171)	57.5 (163)	57.3 (153)
4	59 (165)	59.3 (141)	55.5 (149)
5	60 (162)	60.5 (151)	62.3 (115)
6	62 (165)	62.3 (125)	62.5 (175)

The mean back calculated length and the average observed length for age 1 males were also significantly different among areas ($p < 0.001$) but did not show a consistent pattern of differences.

Table 2: *A. lineatus:* Average back calculated total lengths (TL) of females at the time of annulus formation.

TIRUNELVELI									
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	48	175	46.8					
2	55	182	46.5	53.5				
3	58	171	46.7	53.8	56.6			
4	59	165	46.5	53.5	57.2	58.1		
5	60	162	46.0	53.8	56.5	58.0	58.8	
6	60	165	46.5	53.0	56.3	58.2	58.5	59.2
NAGERCOIL								
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	49.3	165	47.5					
2	56.0	162	48.2	55.3				
3	57.5	163	47.5	54.8	56.5			
4	59.3	141	48.5	55.0	56.3	59.3		
5	60.5	151	48.0	55.5	56.0	59.5	60.5	
6	62.3	125	47.5	55.2	56.5	58.7	60.0	60.5
AUTHOOR								
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	48.7	165	47.0					
2	58.7	132	47.5	54.5				
3	57.3	153	47.8	53.8	56.5			
4	55.5	149	47.5	53.5	55.5	59.5		
5	62.3	115	47.3	54.2	55.8	58.5	60.2	
6	62.5	175	48.5	54.5	56.5	56.5	60.5	61.3

Table 3: *A. lineatus:* Average back calculated total lengths (TL) of males at the time of annulus formation.

TIRUNELVELI								
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	45	135	43.7					
2	54	165	44.5	51.8				
3	58	182	43.5	52.0	57.4			
4	62	151	43.7	51.5	57.5	60.9		
5	64	135	43.5	52.7	58.3	61.2	62.9	
6	66	145	43.2	52.5	58.5	60.5	63.5	64.2
NAGERCOIL								
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	47	162	45.0					
2	52.5	151	45.3	48.5				
3	57.5	155	44.8	47.5	52.7			
4	59.5	152	45.5	47.8	53.5	57.5		
5	62.0	140	45.2	48.5	53.5	57.0	59.3	
6	64.0	115	45.7	48.3	54.7	57.5	60.5	62.5
AUTHOOR								
Annulus group	**Observed mean length**	**N**	**1**	**2**	**3**	**4**	**5**	**6**
1	49	182	48.0					
2	51	145	47.5	49.0				

3	56	125	47.7	48.5	54.3			
4	60	113	48.0	49.5	55.2	58.0		
5	61.5	142	47.2	48.5	55.0	57.8	60.3	
6	68	151	48.0	49.7	55.5	58.2	61.5	65.0

Von Bertalanffy growth equation

Residual plots from the growth models showed near-random patterns, indicating that the von Bertalanffy model adequately described the growth of male and female killifish. The estimated von Bertalanffy growth parameters (Tables 4 and 5) of *A. lineatus* are given Figure 1a, b.

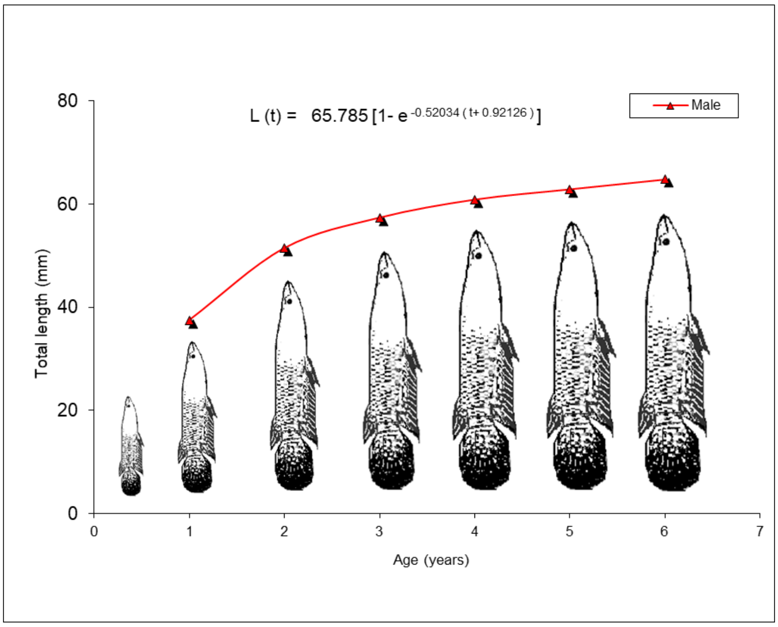

Figure 1(a) ***A. lineatus*****: Length growth curves males collected from August 2022 to July 2044 from river Tambaraparani, Tirnelveli, India.**

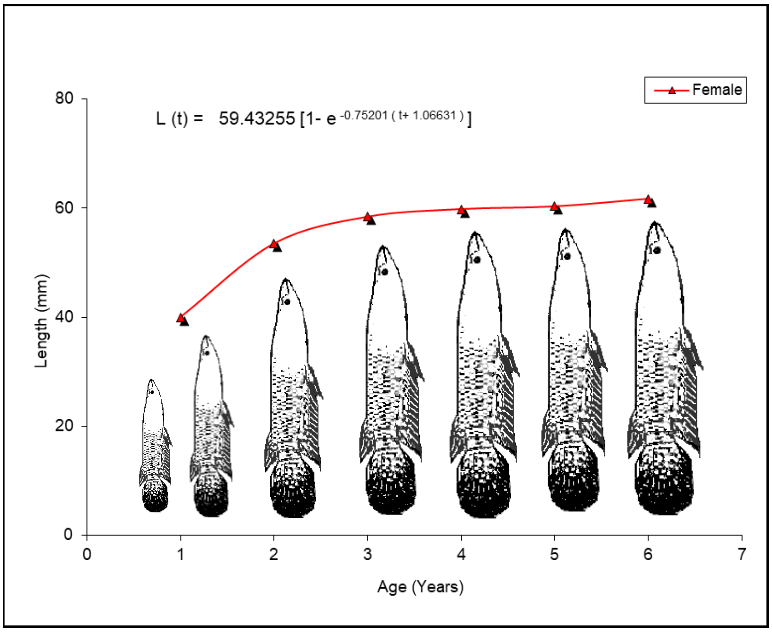

Figure 1(b): ***A. lineatus*****: Length growth curves females collected from August 2022 to July 2024 from river Tambaraparani, Tirnelveli, India.**

The estimated values for male were L_∞ = 66 ± 2.3mm, K = 0.52 ± 0.01 and t_o = -0.92 ± 0.015 (r^2 = 0.973). Mean incremental growth was slow during the first two years and rapid during the rest of life. During this period killifish male added 3 to 5mm of the body length each year. For female *A. lineatus* the VBFG parameters were

L_∞ = 59 ± 2.6mm, K = 0.75 ± 0.35 and t_o = -1.066 ± 0.005 (r^2 = 0.973). Mean incremental growth was rapid during the first two years and thereafter the growth was slower.

Table 4: *A. lineatus*: Estimation of length at age t using von Bertalanffys' growth equation for males.

K = 0.52 / year L_{α} = 66 mm t_0 = -0.92 / year

t	$(t-t_0)$	$e^{-k(t-t_0)}$	$1-e^{-k(t-t_0)}$	$L_\alpha[1-e^{-k(t-t_0)}]$ (mm)
1	1.92	0.368	0.632	41.7
2	2.92	0.219	0.781	51.5
3	3.92	0.130	0.870	57.4
4	4.92	0.077	0.923	60.9
5	5.92	0.046	0.954	62.9
6	6.92	0.027	0.973	64.2

$L(t) = L_\alpha[1-e^{-k(t-t_0)}]$
$L(t) = 66[1-e^{-0.52(t+0.92)}]$

Table 5: *A. lineatus*: Estimation of length at age t using von Bertalanffys' growth equation for females.

K = 0.75 L_{α} = 59 mm t_0 = -1.066

t	$(t-t_0)$	$e^{-k(t-t_0)}$	$1-e^{-k(t-t_0)}$	$L_\alpha[1-e^{-k(t-t_0)}]$ (mm)
1	2.066	0.212	0.788	46.8
2	3.066	0.100	0.900	53.5
3	4.066	0.047	0.954	56.6
4	5.066	0.022	0.978	58.09
5	6.066	0.010	0.990	58.8
6	7.066	0.004	0.996	59.2

$L(t) = L_\alpha[1-e^{-k(t-t_0)}]$
$L(t) = 59.4[1-e^{-0.75(t+1.066)}]$

During this period the killifish female added 5 - 7 mm of the body length each year and thereafter 1 to 2 mm for the rest of the years.

Mortality

The monthly record of mortality on various maturity stages and pond mortality and lab mortality in *A. lineatus* showed that mortality was less than 5% in all the months. The mortality rate was more in males. The value of Z (Instantaneous mortality) for all the 24 months is given in Table 6. The monthly mortality values estimated for *A. lineatus* are shown in Table 7. It was observed from the data that the estimate of Z was 1.246 - 1.434 for the males and 1.00 - 1.583 for the females for different months of the study period. Similarly the fishing mortality (F) was 0.258 - 0.586 for the males and 0.035 - 0.349 for the females. The natural mortality (M) was 0.997 - 0.923 for the males and 0.913 - 1.258 for the females.

Table 6: *A. lineatus*: Monthly total instantaneous mortality (Z).

Period	Male	Female
Aug-22	1.408	1.407
Sep-22	1.433	0.583
Oct-22	1.396	1.426
Nov-22	1.434	1.188
Dec-22	1.409	1.191
Jan-23	1.422	1.186
Feb-23	1.365	1.220
Mar-23	1.365	1.205
Apr-23	1.433	1.212
May-23	1.423	1.236
Jun-23	1.433	1.207
Jul-23	1.387	1.194
Aug-23	1.387	1.192
Sep-23	1.374	1.183
Oct-23	1.361	1.175
Nov-23	1.349	1.167

Dec-23	1.336	1.158
Jan-24	1.323	1.150
Feb-24	1.310	1.142
Mar-24	1.297	1.133
Apr-24	1.285	1.125
May-24	1.272	1.117
Jun-24	1.259	1.109
Jul-24	1.246	1.100

Total instantaneous mortality of the males was 1.326/year and that of the females was 1.208/year. The Fishing mortality coefficient was 0.406/year for males and 0.158/year for females. The estimated value of M for males was 0.956/year for males and 1.05/year for females. The estimate of M was calculated using Pauly's (1980) multiple regression equation with VBGF parameters L_∞ = 66mm, K = 0.52/ year for males and L_∞ = 59mm, K = 0.75/year for females at the mean annual temperature (T) of 29.5°C.

Table 7: *A. lineatus*: Monthly record of various mortalities.

Period	Total Instantaneous Mortality(Z)		Fishing Mortality(F)		Natural Mortality(M)	
	Male	Female	Male	Female	Male	Female
Aug-02	**1.408**	**1.407**	0.450	0.149	0.958	1.258
Sep-02	1.433	1.583	0.478	0.349	0.955	1.234
Oct-02	1.396	1.426	0.442	0.172	0.954	1.254
Nov-02	1.434	1.188	0.437	0.035	0.997	1.153
Dec-02	1.409	1.191	0.486	0.204	0.923	0.987
Jan-03	1.422	1.186	0.468	0.229	0.954	0.957
Feb-03	1.365	1.220	0.380	0.055	0.985	1.165
Mar-03	1.365	1.205	0.433	0.070	0.932	1.135
Apr-03	1.433	1.212	0.488	0.089	0.945	1.123
May-03	1.423	1.236	0.488	0.094	0.935	1.142
Jun-03	1.433	1.207	0.479	0.054	0.954	1.153
Jul-03	1.387	1.194	0.422	0.079	0.965	1.115
Aug-03	1.387	1.192	0.463	0.205	0.924	0.987
Sep-03	1.374	1.183	0.389	0.227	0.985	0.956
Oct-03	1.361	1.175	0.365	0.200	0.996	0.975
Nov-03	1.349	1.167	0.396	0.221	0.953	0.946
Dec-03	1.336	1.158	0.412	0.183	0.924	0.975
Jan-04	1.323	1.150	0.358	0.227	0.965	0.923
Feb-04	1.31	1.142	0.357	0.229	0.953	0.913
Mar-04	1.297	1.133	0.323	0.166	0.974	0.967
Apr-04	1.285	1.125	0.350	0.191	0.935	0.934
May-04	1.272	1.117	0.324	0.142	0.948	0.975
Jun-04	1.259	1.109	0.312	0.116	0.947	0.993
Jul-04	1.246	1.100	0.258	0.127	0.988	0.973

Site-specific variation

The site-specific variation observed in three different sampling locations A - Tirunelveli, B - Nagercoil and C - Authoor did not show much variation among the three different places (A, B & C) studied. Only a slight variation was observed in the peak breeding months. In Tirunelveli (A) the peak spawning months were September- December and April whereas in Nagercoil (B) the peak spawning months were December -March and in Authoor (C) it was during October - February. The relationship was studied for a period of 6 months. An analysis of variance and correlation studies showed that the data were highly significant having $p < 0.05$. The attributes such as age, standard length, live fish weight, liver weight, gonad weight, condition factor, hepatosomatic index and gonadosomatic index were considered. The reproductive studies showed similar results in all the three locations. Some slight variation was observed in the number of eggs and the number of oil droplets in the egg of *A. lineatus* in the site specific study.

DISCUSSION

Sex ratio

In the present study the cumulative sex ratio for *A. lineatus* almost conformed to the expected 1:1 in all the months based on the chi-square values showing homogeneity in distribution of the sexes. Only during the peak spawning months the females were slightly more than the males.

Age and growth

In the present study the age of *A. lineatus* was determined using the rings (annuli) present on the otolith. Podrabsky (2017) reported that the otolith method of determination of age and growth was reliable. Brown *et al.*, (2011) reported that otoliths were more accurate than scales for estimating the correct age of fishes. Instead of scales, otoliths were found suitable for determining age in the minnow *Nothobranchius furzerri* (Gwendoline *et al* 2022). The females were larger than the males of the same age; there was no evidence of sex surviving more than two years. The juveniles of *A. lineatus* exhibited faster growth till sexual maturity as reported by Podrabsky (2017) for *Nothobranchius guentheri*. The young fish had extremely rapid growth. In the present study it was observed that the fish *A. lineatus* grew rapidly (Korwin (2012); Podrabsky & Culpepper (2012) in *Austrofundulus limnaeus* and Podrabsky (2017) in *Austrofundulus limnaeu* till sexual maturity in about 95 days. The increase in growth rate in the present study may be related to temperature as observed in by Kapakos *et al*., (2024) in killifishes; Brown *et al.*, (2011) in *Fundulus grandis*; Chaibi *et al* (2015) in *Aphanius fasciatus*; Kamal *et al*., 2009 in *Aphanius sophiae*, Korwin (2012); Podrabsky & Culpepper (2012) in *Austrofundulus limnaeus* and Podrabsky (2017) in *Austrofundulus limnaeu*, Gwendoline *et al.*, (2022) in *Nothobranchius furzeri*, Nester *et al.*, (2025), and Costa WJEM (2017) in *Melanorivulus rossi*.

Growth functions

In the present study of *A. lineatus*, L_∞ was estimated by the von Bertalanffy's growth parameters. L_∞ for the male and the female were 66mm and 59mm respectively. This proved the recent findings that males were larger than females after maturity. The same trend was reported by Nester *et al.*, (2025) that L_∞ for the males and the females were 23.2cm and 28.2cm in *Coryphaenoides rupestris*. Arezon *et al*. (2001) reported the same in the annual fish *Cynopoecilus melanotaenia*. The mean incremental growth was greatest in the first two years in *A. lineatus.* During this time, *A. lineatus* added 7 - 12 in cm each year. Between the third and fourth year, growth decreased to 2 - 5cm and in the subsequent years to 1 - 3cm in total length. The same observation was reported in *Melanorivulus rossi* (Nester *et al.*, (2025), Kapakos *et al*., (2024) in killifishes; Brown *et al.*, (2011) in *Fundulus grandis*; Chaibi *et al* (2015) in *Aphanius fasciatus*; Kamal *et al*., 2009 in *Aphanius sophiae*, Korwin (2012); Podrabsky & Culpepper (2012) in *Austrofundulus limnaeus* and Podrabsky (2017) in *Austrofundulus limnaeu*, Gwendoline *et al.*, (2022) in *Nothobranchius furzeri*, Nester *et al.*, (2025), Costa WJEM (2017) in *Melanorivulus rossi*). *A. lineatus* males attained an average maximum length (L_α) higher than females.

The Bertalanffy length of mathematical expression curves for the males and the females of *A. lineatus* showed a higher growth coefficient for the male (k = 0.5203) when compared to the female (k = 0.752). A similar observation in *Cynopoecilus melanotaenia* was reported by Arenzon *et al*., (2002).

Site-specific variations

The site-specific study of *A. lineatus* showed variation in standard length as well as fecundity in three different localities (Tirunelveli, Nagercoil, Authoor). Kapakos *et al*., (2024) reported the habitat alterations in rivers Arkansas and Ninnescah and observed the highest fecundities in *F. zebrinus*. Fish stocks which were least affected by impoundments and resultant channelization Brown *et al.*, (2011) exhibited the lowest fecundities in *F. zebrinus*.

From the present study it is evident that there was a variation in the egg size in *A. lineatus* in all the three locations *viz*., Tirunelveli, Authoor and Nagercoil. The variation may be due to different ecological conditions. Similarly, increasing temperatures were held responsible for the intraspecific decline in egg size over the spawning season (Kapakos *et al*., (2024) in killifishes; Brown *et al.*, (2011) in *Fundulus grandis*; Chaibi *et al* (2015) in *Aphanius fasciatus*; Kamal *et al*., 2009 in *Aphanius sophiae*, Korwin (2012); Podrabsky & Culpepper (2012) in *Austrofundulus limnaeus* and Podrabsky (2017) in *Austrofundulus limnaeu*, Gwendoline *et al.*, (2022) in *Nothobranchius furzeri*, Nester *et al.*, (2025), and Costa WJEM (2017) in *Melanorivulus rossi*). The site-specific study of *A. lineatus* eggs showed variation in the number of oocytes as well as the number of oil droplets in individual eggs from different locations. There was no relationship between the length of the female and the number of oil droplets.

Mortality

Mortality rates are usually age and sex specific, which means that animals of different ages or sex die at different rates. In many species, the young and old animals die at faster rates than the prime age animals. Often, males have higher mortality rates than females because of activities associated with territorial or mating behaviour.

In the present study the Z estimated was 1.326/year for males and 1.208/year for females. Podrabski (2017) reported that the total mortality (Z) was 2.01 annually for *Fundulus parvipinnis.* The F was found to be low inferring that this species could be exploited further as the 'M' value was found to be high. However to support this finding exploitation rate and maximum sustainable yield (MSY) are to be calculated using the analytic model of Beverton and Holt.

CONCLUSION

The role of sexual differences in the growth, recruitment and mortality of the killifish *A. lineatus* was studied. The observed sex ratio did not deviate from the expected 1:1 sex ratio except during the breeding months when the females were a little more. The maximum age recorded for the male and the female was 6 years. The parameters of the von Bertalanffy growth equation demonstrated that males grew faster to reach a smaller asymptotic length than did females. The total mortality Z estimated were1.326/year for males and 1.208/year for females.

REFERENCES

1. **Arenzon, A., Lemos, C. A. & Bohrer, M. B. C.** The influence of temperature on the embryonic development of the annual fish *Cynopoecilus melanotaenia* (Cyprinodontiformes, Rivulidae). *Brz. J. Biol.*, **2002; 62(4B):** 743-747.
2. **Beverton, R. J. H. & Holt, S. J.** A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapp. *P. V. Reum. CIEM*, **1956; 140:** 67-83.
3. **Brown CA, Gothreaux CT, and Green CC.** Effects of temperature and salinity during incubation on hatching and yolk utilization of Gulf killifish *Fundulus grandis* embryos. Aquaculture, **2011;** 315(3–4): 335–339.
4. **Campana, S. E. & Thorrold, S. R.** Otoliths, increments and elements: Keys to a comprehensive understanding of fish populations? *Can. J. Fish. Aquat. Sci.*, **2001; 58:** 30-38.
5. **Chaibi R, Si Bachir A, and Chenchouni H.** New inland sites for the Mediterranean killifish (*Aphanius fasciatus* Valenciennes, 1821) in the Sahara Desert of Algeria. J Appl Ichthyol, **2015;** 31(6): 1072–1076.
6. **Costa WJEM** Three new species of the killifish genus Melanorivulus from the central Brazilian Cerrado savanna (Cyprinodontiformes, Aplocheilidae). ZooKeys, **2017;** 645: 51–70.
7. **Gwendoline Astre, Eitan Moses, Itamar Harel,** The African turquoise killifish (Nothobranchius furzeri): biology and research applications, Editor(s): Livia D'Angelo, Paolo de Girolamo, Laboratory *Fish in Biomedical Research*, Academic Press, **2022;** 245-287.
8. **Kamal S, Bakhtiyari M, Abdoli A, Eagderi S, and Karami M.** Life-history variations of killifish (*Aphanius sophiae*) populations in two environmentally different habitats in central Iran. J Appl Ichthyol, **2009;** 25(4): 474–478.
9. **Kapakos, Y., Barbieri, R., and Zimmerman, B.** Embryonic and larval development of a highly threatened killifish: ecological and conservation implications. *Environ Biol Fish*, **2024; 107:** 293–305.
10. **Korwin-Kossakowski M.** Fish hatching strategies: a review. Reviews in Fish Biol Fish, **2012;** 22(1): 225–240.
11. **Le Cren ED** The length–weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J Anim Ecol, **1951;** 20: 201–219.
12. **Mazzoni, R. & Caramaschi, E. P.** Size structure, sex ratio and onset of sexual maturity of two species of *Hypostomus*. *J. Fish Biol*., **1995; 47:** 841-849.
13. **Nester, T.L., López-Solano, A., Perea, S.** ***et al.*** Genomic population structure and diversity of the endangered *Aphanius iberus*: strategies for killifish conservation. *Conserv Genet*, **2025; 26:** 263–277.
14. **Podrabsky JE.** Embryonic development of the annual killifish Austrofundulus limnaeus: An emerging model for ecological and evolutionary developmental biology research and instruction. Dev Dyn, **2017**; 246(11): 779-801.
15. **Podrabsky JE, Culpepper KM.** Cell cycle regulation during development and dormancy in embryos of the annual killifish *Austrofundulus limnaeus*. Cell Cycle, May. 1, 2012; 11(9): 1697-704.
16. **Sokal, R. R. & Rohlf, F. J.** Biometry 2nd ed. W. H. Freeman and Co., San Francisco, New York, **1981;** 859.