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AGE GROWTH AND MORTALITY OF *Aphanius fasciatus* (Nardo, 1827) (PISCES: CYPRINODONTIDAE) IN THE MESOLONGI AND ETOLIKON LAGOONS (WESTERN GREECE).

J. LEONARDOS & A. SINIS

Abstract Age growth and mortality of *Aphanius fasciatus* from Mesolongi and Etolikon lagoons were studied. Fishes of both sexes from the Mesolongi Lagoon were heavier for the same length than those from Etolikon Lagoon. Age was determined by means of scale reading and the annual ring formation was found to be once a year occurring during February. From back calculated total lengths it was found that females were larger than males, of the same class age and fishes of both sexes from Mesolongi lagoon were larger than fishes from Etolikon lagoon. The overall sex ratio was males: females 1: 2.44 and varied seasonally. During the reproductive period and before the new-borns recruitment, the sex ratio was 1: 5.9 (males: females) but after the spawning season and the new-borns recruitment the sex ratio was 1:1.3 (males: females). Total instantaneous mortality rates of males were also higher than of females and mortality rates of both sexes from Etolikon lagoon were higher than from Mesolongi lagoon.

Περίληψη Μελετήθηκε η ηλικία, η αύξηση και η θνησιμότητα του *Aphanius fasciatus* από τις λιμνοθάλασσες Μεσολογγίου και Αιτωλικού. Διαπιστώθηκε ότι τα άτομα και των δυο φύλων που προέρχονταν από τη λιμνοθάλασσα Μεσολογγίου ήταν βαρύτερα για το ίδιο μήκος από αυτά που προέρχονταν από τη λιμνοθάλασσα του Αιτωλικού. Η ηλικία μελετήθηκε από τα λέπια και βρέθηκε ότι σχηματίζεται ένας ετήσιος δακτύλιος τον Φεβρουάριο. Από τα ανάδρομα υπολογισμένα ολικά μήκη διαπιστώθηκε ότι τα θηλυκά ήταν μεγαλύτερα από τα αρσενικά της ίδιας κλάσης ηλικίας. Επιπλέον τα ψάρια και των δυο φύλων που προέρχονταν από τη λιμνοθάλασσα του Μεσολογγίου ήταν μεγαλύτερα από αυτά που προέρχονταν από τη λιμνοθάλασσα του Αιτωλικού. Η συνολική αναλογία φύλων ήταν 1: 2.44 (αρσενικά: θηλυκά αντίστοιχα), η οποία μεταβάλονταν εποχικά. Κατά τη διάρκεια της αναπαραγωγής και πριν την είσοδο των νεοεισερχομένων στο πληθυσμό ατόμων ήταν 1:5.9, ενώ αμέσως μετά την είσοδο των νεοεισερχομένων στο πληθυσμό ατόμων ήταν 1:1.3. Ο συντελεστής ολικής θνησιμότητας των αρσενικών ήταν μεγαλύτερος από αυτό των θηλυκών, επίσης οι τιμές του συντελεστή ολικής θνησιμότητας των ψαριών που προέρχονταν από τη λιμνοθάλασσα του Αιτωλικού ήταν μεγαλύτερος από αυτές των ψαριών που προέρχονταν από τη λιμνοθάλασσα του Μεσολογγίου.

INTRODUCTION

Aphanius fasciatus (Nardo, 1827) is commonly known in Greece under the name zabarola. It is an euryhaline teleost fish which lives in lagoons, salt marshes, shallow brackish water ecosystems and inland waters. It forms large populations which reside in the shore zone of the lagoon.

According to KIENER & SCHACHTER (1974) there are four representatives of the genus *Aphanius* in the Mediterranean namely *Aphanius fasciatus* (Nardo, 1827), *Aphanius iberus* (Cuv. & Val., 1846), *Aphanius dispar* (Ruppell, 1828) and the freshwater fish *Aphanius mento* (Heckel, 1843).

The distribution of this species occurs in the central and eastern coastal zone of

the Mediterranean (Corsica, Italy, Yugoslavia, Greece, Cyprus, Turkey, Israel, Egypt - including the Suez Canal, Algeria and Tunisia) (GOREN & RYCHWALSKI 1974, BOUMAIZA *et. al.*, 1979, BOUMAIZA 1980, VILLWOCK 1985).

In this study, information on the age, growth and mortality of *Aphanius fasciatus* is presented, for individuals which were collected from Mesolongi and Etolikon Lagoons. Prevailing environmental parameters of the habitat, such as salinity, depth and temperature of the water and vegetation cover were examined in order to relate their influence on the biological characteristics in the fish species.

MATERIALS AND METHODS

The group of lagoons Mesolongi and Etolikon (38°15'-38°30'N, 21°05'-21°35'E) in Western Greece, are among the largest in the Mediterranean and have a total area of about 150 Km^2. They have been formed by the joined siltation of two neighbouring rivers the Acheloos and Evinos. The Etolikon lagoon makes up the northern part of the ecosystem, while the Mesolongi lagoon the central and southern part, which is connected to the south with the Patraikos Gulf (Fig.1).

Sampling was carried out monthly at two different places areas (Stations) in the Mesolongi and Etolikon lagoons (Fig. 1). Samples were collected using seine nets with a mesh size of 2.5 mm, length of 15m, a height of 1.5 m at the edges and 2 m in the centre, ended to a sac with diameter of 1.5 m and length of 3 m. The design of the net was based

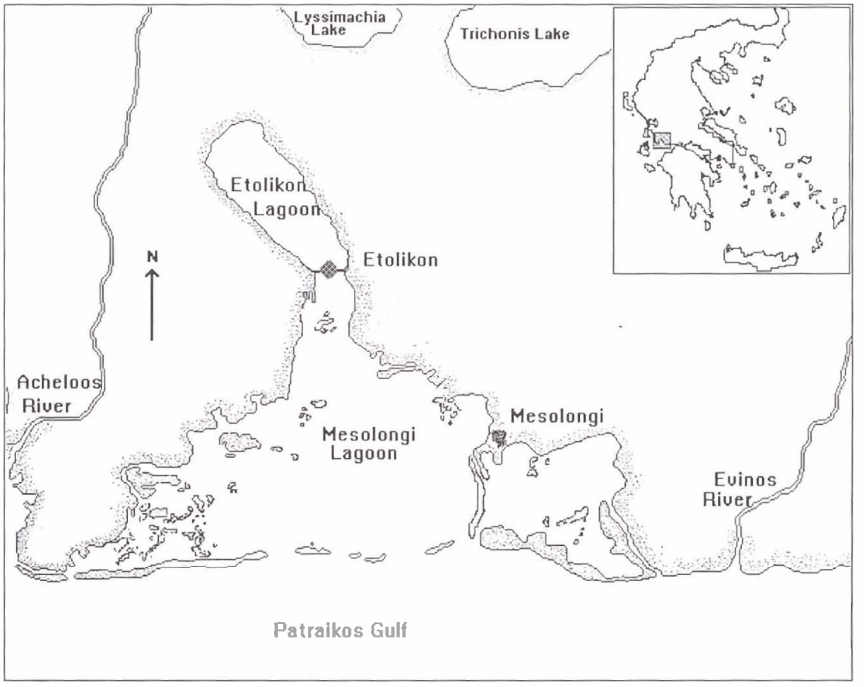

Fig. 1 Map of the Mesolongi and Etolikon lagoons.

on those used by local fishermen for catching fish of small size. A total of 1222 specimens with a length from 21.13 to 70.63 mm were obtained from monthly collections during June 1989 to July 1990. Caught fish were rinsed in clean freshwater and placed immediately in 4% neutral formalin and transported to the laboratory where their total length (±0.01 mm) and dry weight of eviscerated fish (±0.1 mg) was recorded. The sex was determined from the external characteristics but also by examination of the gonads.

Age was determined from the scales, which always removed from the left side of the body between the end of the thoracic fin and the beginning of the dorsal fin.

Observations were made using a dissecting microscope (X 30). In addition we use image analysis system. The total radius of the scale and the radius of the annual ring were measured as the smallest distance from the center of the scale to the distal edge (CHANG *et al.,* 1980). In order to determine the time of formation of the annual ring the width of the margin was defined as the percentage difference between the total radius (R) of the scale and the radius of the last annual ring (R_n). Marginal growth was examined in all scales aged during the whole sampling period.

The relationships: total length - somatic weight (W), total length - scale radius were determined for each sex and each lagoon, separately, and were tested statistically for differences between the regression coefficients of the sexes and the lagoons (ANCOVA). Differences were deduced using paired comparisons of slopes - Tukey test (ZAR 1984).

Back-calculated lengths at age of individual fish were estimated from the total length - scale radius regressions using Fraser-Lee method (BAGENAL & TECH 1978) and was tested for differences between the sexes and lagoons. The von Bertalanffy growth equation was fitted to mean back-calculated length at age using the Ford - Walford method (EVERHART & YOUNG 1975).

Total instantaneous mortality rates (Z) were calculated for each sex and each lagoon using the cumulated catch-curve. All catch - curves were tested for differences in slopes (Z/k) between sexes and between lagoons using ANCOVA. Total instantaneous mortality rates (Z) were compared between the sexes and between lagoons using means and confidence limits of means.

Age growth and mortality rates were estimated using samples which were collected once (in April 1990).

RESULTS

The Mesolongi lagoon is the most typical type of ecosystem of this territory, with an average depth of 0.8 m. Its bottom is covered with rich vegetation. The water temperature ranged from 7-27 ^{0}C, had steady salinity gradient along the axis " land to sea " which ranged from 14 - 23.5 ppt. Etolikon lagoon is a deep "atypical" meromictic lagoon, its main characteristic being the permanent, throughout the year, thermal and chemical vertical stratification. Close to the shore the study area is quite deep with an average depth of 12 m and deepest of 29 m. The lagoon bed near the shore is sandy, the temperature ranged from 8 -28.7 ^{0}C. The salinity of surface and coastal waters is low (10-22 ppt) which is caused by great influxes of agricultural drainage waters and by the restricted connections of this area with the Mesolongi lagoon and through it with the open sea.

The age composition, was found to differ between the sexes and between lagoons. At Etolikon lagoon young individuals were dominant. At this lagoon the longest female

Table 1 Parameters of the relationship Weight (W) - Length (L) of *Aphanius fasciatus* with respect to sex and sampling station.

Station	Sex	$W=a\,L^{b}$	95% C.L of b	N	R^2	P
	Female	$W= 5.95\ 10^{-3}\ L^{3,44}$ #	3.42 - 3.46	276	0.99	<0.001
Mesolongi	Male	$W= 6.48\ 10^{-3}\ L^{3,40}$ *	3.35 - 3.45	185	0.99	<0.001
	Total	$W= 6.12\ 10^{-3}\ L^{3,42}$ +	3.40 - 3.45	461	0.99	<0.001
	Female	$W= 8.26\ 10^{-3}\ L^{3,22}$ #	3.14 - 3.30	137	0.97	<0.001
Etolikon	Male	$W= 7.58\ 10^{-3}\ L^{3,26}$ *	3.20 - 3.32	160	0.98	<0.001
	Total	$W= 7.53\ 10^{-3}\ L^{3,27}$ +	3.24 - 3.30	296	0.99	<0.001

: P<0.001 ; * : P<0.001
+ : P<0.001

Table 2 Parameters of the relationship total length TL (mm) - scale radius R (mm) of *Aphanius fasciatus* with respect to sampling station and sex.

Station	Sex	TL= a + b*R	95% C.L. of b	R^2	N
	Female	TL = 12.2 + 30.22 R #	29.55 - 30.90	0.96	276
Mesolongi	Male	TL = 9.1 + 31.14 R &	30.14 - 32.14	0.96	180
	Total	TL = 11.3 + 30.36 R	29.73 - 31.00	0.95	461
	Female	TL = 10.7 + 28.41 R #	26.98 - 29.85	0.92	137
Etolikon	Male	TL = 11.2 + 28.15 R &	27.13 - 29.17	0.95	160
	Total	TL = 9.1 + 31.42 R	30.50-32.35	0.94	297
Total		TL = 10.5 + 30.60 R	30.10 -31.21	0.92	973

#: P=0.01; &: P<0.001

caught during the course of the study had a length of 70.63 mm and an age of 6+. At Mesolongi lagoon 9.7 % of the individuals had an age greater than 4 years, Etolikon lagoon only 1.6% of the individuals were older than 4 years.

Data indicated that one annulus was formed per year. The largest percentages of individuals with an annulus at the edge of the scale were found during February.

The relationship between total length (TL) - somatic weight (W) of the fish was examined for each sex separately and for each sampling station (Table 1). The slopes of the logarithmic equations were examined using ANCOVA which showed that there was no significant difference between the sexes at both lagoons (Mesolongi: 3.44 = 3.40, Etolikon: 3.22 = 3.26) In addition, there were significant differences between individuals of the same sex from two lagoons. Both sexes from Mesolongi lagoon were heavier than those from Etolikon lagoon, for the same length (females: 3.44 > 3.22, males: 3.40 > 3.26, respectively).

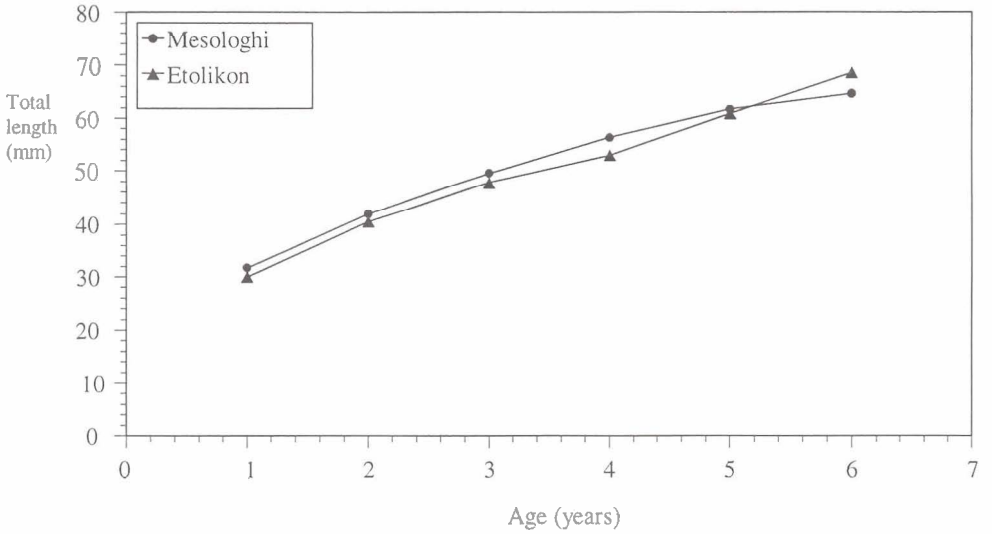

Fig. 2 Von Bertalanffy growth curves fitted to mean back-calculated total length for *Aphanius fasciatus* from Mesolongi and Etolikon lagoons

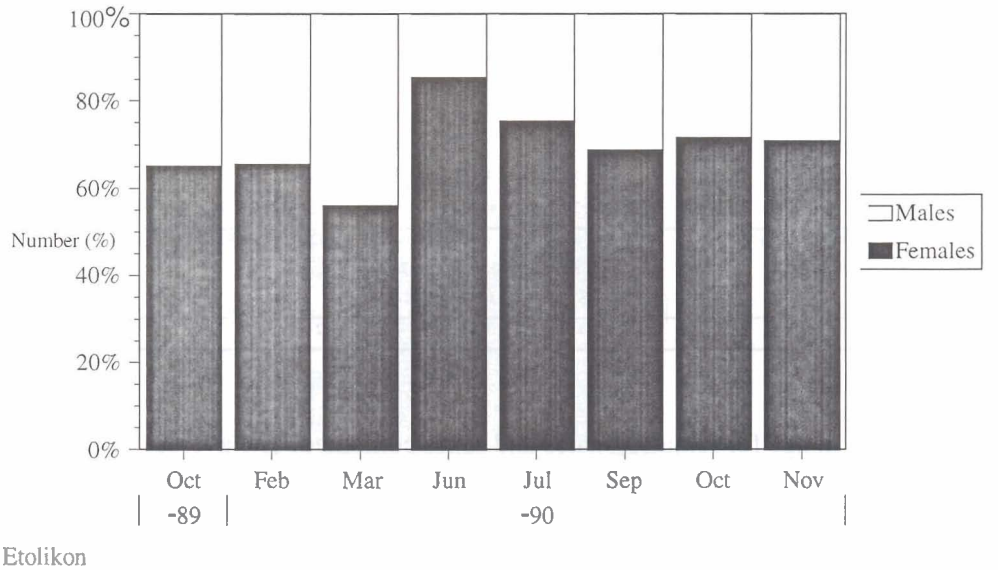

Fig. 3 Seasonal sex ratio (%) of *Aphanius fasciatus* from Etolikon Lagoon.

The relationship between total length (TL) and scale radius (R) (x30) was studied for each sex separately and for each lagoon. Linear regression gave the best fit (Table 2).

The slopes of lines indicated that there were no significant differences between sexes at any of lagoons, however there were significant differences only for males between two lagoons (Table 2). Intercepts from these regressions were used to back-cal-

Table 3 Back-calculated total lengths (mm) at age of both sexes of *Aphanius fasciatus* combined at Mesolongi and Etolikon lagoons (MTLC =mean total length at capture, N= number of fish).

Mesolongi lagoon (sexes combi

Age				Age (Years)					
(Years)	MTLC	95% c.i.	N	1	2	3	4	5	6
0 +	27.46	(26.87-28.05)	83						
1 +	37.83	(37.08-38.42)	130	31.22					
2 +	47.22	(46.51-47.92)	107	32.23	41.57				
3 +	53.71	(52.85-54.57)	61	31.52	42.11	49.06			
4 +	60.14	(58.98-61.30)	24	31.74	43.10	50.44	56.24		
5 +	64.85	(63.55-66.15)	11	33.21	43.25	50.52	56.76	61.86	
6 +	67.32	(65.74-68.90)	2	32.40	41.97	49.22	55.13	60.55	64.64
All classes total length				31.71	42.00	49.56	56.33	61.66	64.64
95% c.i. of total length				(31.40-32.02)	(41.58-42.42)	(49.03-50.08)	(55.46-57.20)	(60.50-62.82)	
N			418	335	205	98	37	13	2

Etolikon lagoon (sexes combi

Age				Age (Years)					
(Years)	MTLC	95% c.i.	N	1	2	3	4	5	6
0 +	27.59	(27.03-28.14)	37						
1 +	36.04	(35.34-36.73)	93	29.22					
2 +	45.69	(44.94-46.43)	96	30.68	40.60				
3 +	52.15	(51.36-52.94)	33	30.38	40.57	47.72			
4 +	55.70	(54.28-57.12)	2	27.54	37.77	45.24	49.77		
5 +	61.17		1	32.38	40.74	48.17	52.81	57.45	
6 +	70.63		1	30.00	41.46	51.88	60.21	64.38	68.55
All classes total length				30.01	40.53	47.76	52.92	60.92	68.55
S.E. of total length				(29.68-30.33)	(40.04-41.01)	(47.03-48.49)			
N			263	133	37	4	2	2	1

culate lengths at age for females, males and sexes combined. The average back- calculated total length of each age group was smaller than the observed length of the same age group at the time of catching and greater than the observed total length at the time of catching, of the previous age group. The lengths that were calculated using the Fraser and Lee's method refer to lengths of individuals, which have just completed their annual ring. This results from the fact that fish were caught after the time of formation of the annual ring.

The mean back - calculated total lengths differed according to sex and the sampling area (Table 3). For all ages and at all sampling stations, where there was a sufficient number of individuals, females were larger than males of the same age group. That was inferred from the non-overlapping confidence limits of the means.

Table 4 Estimation of parameters of the von Bertalanffy equation growth with the method Ford-Waldford

Station	Sex	L_∞	k	to	R^2	von Bert. equation
	Female	78.62	0.245	-1.20	0.99	$L_t = 78.62\ [1-e^{-0.245\ (t+1.20)}]$
	Male	75.68	0.246	-1.19	0.99	$L_t = 75.68\ [1-e^{-0.246\ (t+1.19)}]$
Mesolongi	Both sexes	77.58	0.257	-1.02	0.99	$L_t = 77.58\ [1-e^{-0.257\ (t+1.02)}]$
	Female	108.16	0.115	-2.09	0.99	$L_t = 108.16\ [1-e^{-0.115\ (t+2.09)}]$
Etolikon	Male	80.72	0.178	-1.55	0.99	$L_t = 80.72\ [1-e^{-0.178\ (t+1.55)}]$
	Both sexes	97.78	0.145	-1.58	0.99	$L_t = 97.78\ [1-e^{-0.145\ (t+1.58)}]$
Total		85.69	0.204	-1.18	0.99	$L_t = 85.69\ [1-e^{-0.204\ (t+1.18)}]$

The mean back-calculated total lengths of each age groups were used in the von Bertalanffy growth equation (Table 4) (Fig.2).

Females made up a large proportion of all populations at the beginning of the 1990 reproductive season (overall sex ratio 2.44:1), but sex ratios approached unity in March, just before the start of the new reproductive period (1:2.44). Males decreased in relative abundance during the reproductive period and until after the next juvenile recruitment (Fig. 3).

The fishing net used was capable of catching *A. fasciatus* which had a total length greater than 20mm. Total mortality was determined as the slope of the cumulated catch curve for each sex and each lagoon separately. The mortality coefficients differ significantly between the sexes only at Mesolongi lagoon (Table 5). At Mesolongi lagoon the total mortality coefficient was statistically lower for both sexes than those from Etolikon lagoon (females: 0.55 < 0.93, males: 0.90 < 1.33 for Mesolongi and Etolikon lagoons respectively) (Fig.4).

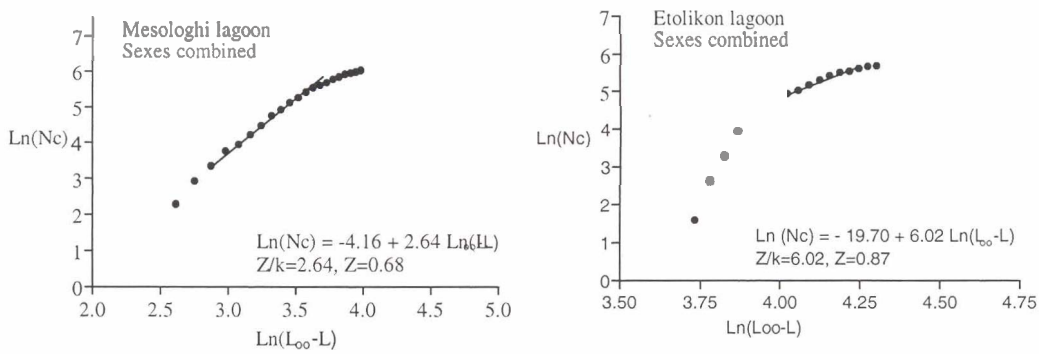

Fig. 4 Cumulated catch curves of *Aphanius fasciatus* from Mesolongi and Etolikon lagoons (sexes combined).

Table 5 Estimation of the total instantaneous mortality coefficient (Z) and the survival rate (S) of *Aphanius fasciatus* using the cumulated catch curves (using Jones & van Zalinge method).

Station	Sex	$Log_e(N_c) = a + b\ Log_e(L_\infty - L)$	Z=b/k	95% c.i. of Z	N	R^2
	Female	$Log_e(N_c) = -3.23 + 2.24\ Log_e(L_\infty - L)$?#	0.549	0.49-0.61	21	0.95
Mesolongi	Male	$Log_e(N_c) = -8.81 + 3.66\ Log_e(L_\infty - L)$?&	0.902	0.80-1.00	18	0.96
	Total	$Log_e(N_c) = -4.16 + 2.64\ Log_e(L_\infty - L)$ ¾	0.678	0.63-0.73	39	0.98
	Female	$Log_e(N_c) = -29.55 + 8.08\ Log_e(L_\infty - L)$ +#	0.929	0.62-1.24	15	0.76
Etolikon	Male	$Log_e(N_c) = -24.52 + 7.44\ Log_e(L_\infty - L)$ +&	1.324	1.03-1.61	14	0.89
	Total	$Log_e(N_c) = -19.70 + 6.02\ Log_e(L_\infty - L)$ ¾	0.874	0.67-1.07	29	0.85

x : P=0.88 ; +: P=0.037 ; * P=0.023 ; # : P<0.001 ; & : P<0.001; ´Y : P<0.001.

DISCUSSION

The values of constant b in the equation total length - somatic weight range from 3.14 to 3.46 in all cases differ significantly from 3 and therefore show an allometric increase (RICKER 1975) (Table1). BAGENAL & TECH (1978) report that differences in values of b for individuals of the same species are observed when there are significant differences in environmental conditions. The values of (the constant) b differ greatly from the values determined by PENAZ & ZAKI (1985) in Lake Mariut, Egypt, was found the relationships: $W=0.0068\ TL^{3.619}$ for females and $W=0.0156\ TL^{2.740}$ for the males.

The reading of scales of *A. fasciatus* demonstrated that at Mesolongi lagoon there were six age groups for both males and females and at Etolikon lagoon six age groups for females and three for males.

In Mesolongi lagoon *Aphanius fasciatus* grows at a faster rate but to a significantly smaller size. These variations in fish growth can be explained as an adaptive response to different environmental conditions (LEONARDOS *et al.* 1996). In all cases, the greatest growth in length occurred in the first year of life (Table 3). Annual growth increment declined steadily after the first year.

Aphanius fasciatus is a small fish and has a relatively short lifespan and high mortality rates. The fish are not used commercially and as a result natural death is the only mortality couse (BEVERTON & HOLT 1956). PAULY (1980) who studied the values of natural mortality (M) in 175 populations of fish found that the populations of *Aphanius fasciatus* from Southern France values of L_∞ were 73 and 63 mm, for k 0.48 and 1.12 1/year and M 1.8 and 2.6 for females and males respectively. By comparison in this study, calculated values of L_∞ were higher, values of k were in all cases lower, and values of M (which correspond to values of Z) were always lower.

Increased male mortality during reproductive period may be due to the fact that shorter male life span reduced competition with juveniles and females for food (HAYNES & CASHNER 1995). PENAZ & ZAKI (1985) report that the characteristics dominance of females in populations of *A. fasciatus* could be due either to interruption of male growth during sexual maturity or to higher male mortality rates or to a shorter life span.

The life history pattern of *Aphanius fasciatus* is characterised by low number of age groups, high growth rates, shorter males life span. Such life history features are

aspects of adaptiveness of small fishes, which successfully exploit productive environments as lagoons.

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J. L. *Par. Papoula 39, 30200 Mesolongi, Greece.*
A.S. *Aristotle University of Thessaloniki, Department of Zoology, P.O. Box 134, 540 06 Thessaloniki, Greece.*