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Population age and sex structure of *Aphanius fasciatus* Nardo, 1827 (Pisces: Cyprinodontidae) in the Mesolongi and Etolikon lagoons (W. Greece)

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Abstract

The population structure of *Aphanius fasciatus* in the Mesolongi and Etolikon lagoonal system was studied, using 5794 fish. Significant differences were observed in the number of individuals of each sex, the age and size composition and survival. The overall males to females sex ratio was 1:2.44, although there was seasonal variation. During the reproductive period the percentage of males in the population decreased significantly, while after reproduction and during recruitment they increased. The females in each age class were larger than the males (40.33 mm and 36.72 mean total length for females and males, respectively). The survival rate of females was greater than males (0.73 for females and 0.60 for males). The strategy of this species is to invest in female individuals. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Aphanius fasciatus; Population structure; Life history; Greek lagoons; Cyprinodontidae

1. Introduction

Aphanius fasciatus (Nardo, 1827) is known in Greece by the common name "zabarola". It is a euryhaline teleost fish which lives in lagoons, salt marshes, shallow brackish water ecosystems and inland waters which are generally unsuitable for other species, due to their high ionic strength and salinity. It is included in Annex II and III of the European Council Directive 92/43 "The Conservation of Natural Habitats, Wildlife and Flora". The species is of no commercial value but it holds a significant position in the food chain of coastal ecosystems, due to its distribution and abundance, and thus may be important in the flow of organic material into and out of coastal ecosystems (Leonardos, 1996).

A. fasciatus is distributed over the central and eastern coastal zone of the Mediterranean, including Corsica, Italy, former Yugoslavia, Greece, Cyprus, Turkey, Israel, Egypt – including the Suez channel, Algeria and Tunisia (Tortonese, 1975; Whitehead et al., 1986; Fischer et al., 1987). In the Mediterranean there are four representatives of the family Cyprinodontidae: A. fasciatus (Nardo, 1827), A. iberus (Cuv. and Val., 1846), A. dispar (Ruppel, 1828), and A. mento (Heckel, 1843) which is found in freshwater (Kiener and Schachter, 1974). A. fasciatus has been studied in terms of its morphometric characteristics

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(Tigano, 1982; Tigano and Ferrito, 1983a), hybrids (Goren and Rychwalski, 1978; Villwock, 1982, 1985), polymorphisms (Boumaiza, 1980; Companini et al., 1984; Tigano, 1991; Parenti and Tigano, 1993), skeletal elements and skeletal abnomalies (Tigano and Ferrito, 1983b, 1985, 1988) and reproduction (Boumaiza et al., 1979; Leonardos and Sinis, 1998). Also, its physiology under conditions of environmental stress (Mastrolia and Gallo, 1989), its biology, growth and mortality in relation to different environmental conditions (Leonardos et al., 1996) and its embryonic and post-embryonic development (Leonardos and Sinis, 1997b) have been studied. In the present work, information on the population structure of A. fasciatus in the Mesolongi and Etolikon lagoon system is presented.

2. Study area

The Mesolongi, Etolikon and Klisova lagoon system is located in Western Greece $(38^{\circ}18'36'' \text{ N-}$

 $21^{\circ}32'00''$ E) (Fig. 1). It has a total surface area of about 150 km² and is one of the larger lagoon system in the Mediterranean. The Etolikon lagoon is of tectonic origin and forms the northern part of the ecosystem. The Mesolongi lagoon was formed through the sedimentary action of two neighboring rivers, the Acheloos and the Evinos and makes up the central and southern part of the system. It is connected to the south with the Patraikos Gulf. The Mesolongi lagoon has an average depth of 0.8 m and the bottom is covered with rich vegetation. The water temperature ranges from 7°C to 27.8°C and the salinity from 14 to 23.5 ppt. The Etolikon lagoon has an average depth of 12 m and a maximum of 33 m. It has a sandy bottom at the sampling sites. The water temperature ranges from 8°C to 28.7°C and the salinity from 10 to 22 ppt.

3. Material and methods

Samples were collected monthly from the Mesolongi and Etolikon lagoons (Fig. 1), from April 1989



Fig. 1. Map of the Mesolongi and Etolikon lagoon system.

to January 1991. The 5794 specimens caught ranged in total length from 15.48 to 70.63 mm.

A large number of preparatory samplings using several types of fishing gears were carried out in various places of the lagoonal system, to estimate the gear selectivity, the possibility of fish emigration during the year, and to examine if there are unequally sexed shoals.

Samples were caught using a fry fishing net (dragnet) with a mesh size of 2.5 mm, length of 15 m and with a height of 1.5 m at the edges and 2 m in the center. The net terminated in a back 3 m long and 1.5 m in diameter. The design of the net was based on the nets used by local fishermen for catching the small fish. The fish were rinsed with freshwater and immediately placed in neutralized formalin (4%), until examination.

The total length of all fish was measured using a digital micrometer (± 0.01 mm). The body weight was measured using an electronic balance $(\pm 0.1 \text{ mg})$ after the removal of the digestive tract and gonads. The sex was determined from external characteristics, since A. fasciatus exhibits sexual dimorphism. The age was determined from the scales taken 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 stereoscope with transmitted and reflected light (Jearld, 1983). Marks were identified by standard criteria (Bagenal and Tesch, 1978), especially cuttingover of circuli in the lateral field, close spacing of circuli followed by wider spacing in the anterior field. Scale reading was difficult due to the high proportion of regenerated scales especially in the older age groups. To determine which parameters affect the values of the length and weight of fish, multiple analysis of variance (MANOVA) was used (Zar, 1984).

The survival rate (S) was estimated for each sex separately using the equation:

$$S = \frac{T}{(T + \sum N + T - 1)},$$

where $T=N_1+2N_2+3N_3+4N_4+\cdots$, $\sum N=N_0+N_1+N_2+N_3+\cdots$, and N_i is the abundance of each age class. The variance of values of *S* was calculated from the equation (Chapman and Robson, 1960):

$$V(S) = S\left[\frac{S - (T - 1)}{\sum N + T - 2}\right].$$

4. Results

4.1. Sex ratio

Of the total number of fish caught, 2795 were female and 1145 were male giving an overall sex ratio of 2.44:1 (x^2 =690.1, P<0.001). The ratio varied seasonally and demonstrated large differences in values. The percentage of males was highest in the early spring (43.80% in March) and lowest in summer (14.40% in June and 24.50% in July). The sex ratio also appears to be dependent on the size class. For the length class 20–40 mm, which corresponds to the newly-recruited individuals of less than one year, the sex ratio did not differ significantly from 1:1 in the winter and up to the beginning of spring. However, at the end of spring and beginning of summer the percentage of males in the population declined significantly (Table 1).

4.2. Age composition

Overall, the percent female and male population in each age class was as follows for females and males, respectively: age 0+, 11.3% and 10.77%; age 1+,

Table 1						
The percentage of male A.	fasciatus in each size	e class in monthly	samples from th	e Mesolongi ar	nd Etolikon lagoo	n system

Size class (cm)	October 1989	February 1990	March 1990	June 1990	July 1990	September 1990	October 1990	November 1990
2–4	78	50	56	19	30.2	27	39	38
4–5	32.5	22.6	37.5	20.5	29.4	11.8	10.9	27.5
5-6	7.8	46.9	4.2	4.2	0	0	3.2	5.7
6–7			0	0	0	0	0	0

Table 2

I. Leonardos, A. Sinis/Fisheries Research 40 (1999) 227-235

Total length (TL) (mm)	Num	Number of fish per age and sex														
	0+	0+		1+		2+		3+		4+		5+		6+		
	F	М	F	М	F	М	F	М	F	М	F	М	F	М		
20-22	4	3	1												8	
22-24	12	8	1												21	
24-26	2	13	1												16	
26-28	25	22	5	6											58	
28-30	18	18	6	33											75	
30-32	2	21	19	27		2									71	
32-34	16	9	37	68	2	9									141	
34-36	4	7	47	75	9	12									154	
36-38	2	3	44	87	1	11									148	
38-40			42	71	2	18									133	
40-42			44	62	33	31	2	1							173	
42-44		1	34	4	36	48	5	6							134	
44-46			19	29	42	41	8	7							146	
46-48			12	14	47	38	1	11	1						124	
48-50			5	6	39	2	25	14	1	1					93	
50-52				3	3	18	4	15	5	4					52	
52-54			1	1	33	9	57	9	1					1	112	
54-56					15	3	3	5	12						38	
56-58					6	2	22	1	12	1	2	1		1	48	
58-60					1		12	4	13	1	3				34	
60-62							2		7	1	5		2		17	
62-64					1				2	1	1				5	
64-66									2		6		2		10	
66–68									1		2		1		5	
68–70													1		1	
70–72													1		1	
Total	85	105	318	486	270	244	141	73	57	9	19	1	7	3	1818	

Size and age composition of females (F) and males (M) of A. fasciatus from the Mesolongi and Etolikon lagoon system

29.78% and 53.5%; age 2+, 30.34% and 26.9%; age 3+, 19.90% and 7.49%; age 4+, 6.20% and 0.92%; age 5+, 1.8% and 0.10%; age 6+, 0.70% and 0.31%. The age composition differed between the sexes, with a higher percentage of females in the older age classes (Table 2).

To study length composition according to age, total length keys were compiled for females and males separately. The total length – age keys were generated from data on all fish which were aged from scale recognition. The age distribution was based on 2 mm total length intervals (Table 3). The age groups were characterized by a large spread and overlapping of lengths. This overlapping between successive age classes is expected for species with an extended reproductive period.

4.3. Length composition

Female specimens were longer than males in all length classes, especially in the longest length classes (Table 4). Fig. 2 shows the length composition and the relative number of fish (%) examined in each of the eight monthly samples taken between October 1989 and November 1990. The lengths ranged from 15.48 to 70.65 mm. The shorter specimens were more abundant in the summer months, which indicates that recruitment starts in June and ends in September.

4.4. Comparison according to sex

The mean total length of all fish examined was 39.07 mm and individual fish ranged in length from

Total length class TL (mm)	Number of fish (%) per age and sex																	
	Femal	Female									Male							
	0+	1+	2+	3+	4+	5+	6+	Total	0+	1+	2+	3+	4+	5+	6+	Total		
20–22	80	20						5	100							3		
22-24	92.3	7.7						13	100							8		
24-26	66.7	33.3						3	100							13		
26-28	83.3	16.7						30	78.6	21.4						28		
28-30	75	25						24	35.3	64.7						51		
30-32	9.5	90.5						21	42	54	4					50		
32-34	29.1	67.3	3.6					55	10.5	79.1	10.5					86		
34–36	6.6	78.3	15					60	7.4	79.8	12.8					94		
36–38	4.3	93.6	2.1					47	3	86.1	10.9					101		
38–40		95.4	4.6					44		79.8	20.2					89		
40-42		55.7	41.8	2.5				79		66	33	1				94		
42-44		45.3	48	6.7				75	1.7	67.8	81.4	10.2				59		
44-46		27.5	60.9	1.16				69		37.7	53.2	9.1				77		
46-48		19.8	77	1.6	1.6			61		22.2	60.3	17.5				63		
48-50		7.1	55.8	35.7	1.4			70		26.1	8.7	60.9	4.3			23		
50-52			25	33.3	41.7			12		7.5	45	37.5	10			40		
52-54		10.9	35.9	62.3	10.9			92		5	45	45			5	20		
54–56			50	10	40			30			37.5	62.5				8		
56–58			14.3	52.4	28.5	4.8		42			33.3	16.7	16.7	16.7	16.6	6		
58-60			3.4	41.4	44.8	10.3		29				80	20			5		
60-62				12.5	43.8	31.3	12.5	16					100			1		
62–64			25		50	25		4					100			1		
64–66					20	60	20	10										
66–68					25	50	25	4							100	1		
68–70							100	1										
70–72							100	1										
Total	9.5	35.5	30.1	15.7	6.3	2.1	0.8		11.4	52.8	26.5	7.9	0.9	0.1	0.3			

> Table 3 Age – total length keys for female (F) and male (M) of *A. fasciatus* from the Mesolongi and Etolikon lagoon system

15.48 to 70.65 mm. Of the total number of fish, 3768 were female, which ranged in length from 15.48 to 70.65 mm and had a mean total length of 40.33 mm. The male fish (2026 specimens) ranged in length from 21.56 to 68.12 mm, with a mean total of 36.72 mm. The mean total length was lowest in the summer and highest in the winter. The values were 41.80, 41.20, 41.80 and 44.20 mm for spring, summer, autumn and winter, respectively. The mean body weight of 1913 fish was 956.89 mg, and ranged from 65.0 to 4598.9 mg. The mean female body weight was 1198.4 mg and individual weight ranged from 84.3 to 4589.9 mg. The mean male body weight was 679.22 mg and individual weights ranged from 65 to 4215.7 mg. The values of mean body weight had

a minimum of 916.9 mg in spring and maximum of 1019.0 mg in winter. Statistical analysis (MANOVA) showed that females had greater total length and greater body weight than males in each age class and each sampling season (F=58.721, P<0.001; F=90.98, P<0.001 for total length and body weight, respectively).

4.5. Survival

The survival rate (S) was calculated using the equation of Chapman and Robson (1960). Its value for females was greater than that for males: females, S=0.726, $v(S)=8.78\times10^{-5}$; males, S=0.601, $v(S)=11\times10^{-5}$.

Table 4

95% C.I. Age MTLC Ν Age (years) (years) of TL 1 2 3 4 5 6 Females^a 27.49 22.24-32.75 75 0 +38.67 29.07-48.26 67 31.55 1 +2 +48.04 41.52-54.56 124 32.90 42.58 47.92-59.23 3 +53.58 70 31.73 42.06 48.92 4 +60.10 54.33-65.87 24 31.66 42.81 50.16 55.96 60.53-69.17 64.85 11 33.31 43.35 50.46 61.26 5+56.47 69.38 65.90-72.85 33.21 52.04 58.99 63.43 67.39 6 +2 43.61 All classes total length 32.24 42.49 49.43 56.28 61.57 67.39 50.58-61.98 95% C.I. of total length 27.13-37.36 37.32-47.67 44.47-54.38 56.37-66.76 63.99-70.80 298 232 108 38 14 2 Ν Males^b 0 +27.51 23.45-31.58 45 36.47 29.59-43.36 161 29.94 1 +2 +44.42 37.54-51.30 81 29.69 39.39 3 +51.84 44.70-58.99 23 30.20 40.54 47.69 4 +59.22 53.81-64.63 2 30.94 30.94 49.36 54.78 5+6+66.51 1 29.23 38.76 46.57 52.64 58.71 63.04 All classes total length 29.89 39.65 47.77 54.07 58.71 63.04 25.27-34.52 34.15-45.15 41.96-53.59 49.23-58.91 95% C.I. of total length Ν 268 105 26 3 1 1

Back-calculated total lengths (mm) at age and von Bertalanffy growth equation parameters of female and male A. fasciatus from Mesolongi and Etolikon lagoons

MTLC=mean total length at capture; TL=total length; N=number of fish.

^a von Bertalanffy growth equations parameters for females L_{∞} =94.44, k=0.16, t_0 =-1.58.

^b von Bertalanffy growth equations parameters for males: L_{∞} =79.22, k=0.22, t₀=-1.14.

5. Discussion

A. fasciatus in the Mesolongi and Etolikon lagoons spends its life in shallow brackish water and does not emigrate, thus during the sampling representatives parts of the population were caught. The proportion of males and females in the population appears to depend on size, age, and reproduction period. There were significant differences in the ratio of males to females in the total number of fish sampled, and also in the monthly samples. At the end of spring and the beginning of summer, the percentage of females increases (Fig. 2), and the survival of males is lower than that of females. This coincides with the reproductive period, which has mostly been completed by the middle of summer (Leonardos and Sinis, 1998). The sex ratio of newly hatched fry is 1:1 (Leonardos and Sinis, 1997b) and the same ratio is maintained during the recruitment, and until the first reproductive

period. The almost equal ratio of males to females at relatively small sizes indicates that equal numbers of the two sexes are hatched and enter the population, while an unequal sex ratio at larger sizes indicates that more males die voung (Table 1). The unequal sex ratio for mature fish reflects different survival rates for males and females. The selective predation of males may result from their intense courtship coloration, which makes them more visible to predators (and more easily attacked). However, it has been shown that females in all cases, especially in extreme environmental conditions, have a higher survival rate than males (Leonardos et al., 1996). Penaz and Zaki (1985) reported that the characteristic dominance of females in populations of A. fasciatus in Egypt (1:2.1, males:females) could be explained by the fact that males stop growing at maturity and by the higher mortality rates of males. Haynes and Cashner (1995) in a study of mosquito-fish, Gambusia affinis, populations in



Fig. 2. Size composition of A. fasciatus in monthly samples from the Mesolongi and Etolikon lagoon system.

southeastern Louisiana found that females constituted a greater percentage of the population during the commencement of the reproductive period, while the sex ratio reached 1:1 immediately after the completion of the reproductive period and during recruitment. This was attributed to the shorter life span of males as well as to their lower survival rate under conditions of environmental stress (extreme temperatures, hypoxia, overcrowding, starvation). It appears that the strategy of the species, in terms of the sex ratio, is the "investment" in females. This is brought about through the selective predation of males or the higher survival rate and greater longevity of females, or the greater endurance of females to environmental stress (Leonardos et al., 1996).

The analysis of size and age showed that *A. fasciatus* is a small-sized fish with populations mainly of young individuals. Boumaiza (1980) reported that the largest female encountered originated from Lake Nord, Tunisia, and was 58.5 mm long. Kiener and Schachter (1974) found that the largest female *A. fasciatus* in the Comacchio lagoon was 75 mm long, while the largest male was 63 mm. In the Etolikon lagoon, the largest female was 70.6 mm (Leonardos, 1996). In a relatively isolated part of the Klisova lagoon (Fig. 1), an area nearby the present study area, a male specimen 75.5 mm long was collected (Leonardos, 1996), which is the largest recorded for the species.

A. fasciatus starts to reproduce in April (Leonardos and Sinis, 1998). The incubation period of eggs is short and is followed by the hatching of larvae with a length of 6–7 mm (Leonardos and Sinis, 1997b). As a result, the first recruited fish are in June samples. The presence of small fish in June and July is a result of the fast growth of newborn fish (Fig. 2).

Small body size is one life history strategy of *A*. *fasciatus*, as it is for most fish that complete their life cycle in lagoons. The lagoon environment is unstable and unpredictable, and small body size constitutes an adaptive characteristic which favors survival in such conditions. In unstable and predictable conditions, especially such as those of the Etolikon lagoon (Leonardos and Sinis, 1997a), the evolutionary mechanisms lead to early sexual maturity with relatively high reproductive effort (Adams, 1980). The result is that sexual maturity will be reached at a small size and post-breeding survivorship will be reduced (Wooton,

1984, 1990). A. fasciatus, which follows this strategy, has short incubation period, high hatching rate of eggs and a high survival of newborn fish (Leonardos and Sinis, 1997b) early sexual maturation, high reproductive effort and an extended reproductive period (Leonardos and Sinis, 1998). In addition, small body size is an adaptive characteristic which allows fish to colonize and exploit widespread microenvironments in the areas of their distribution, which would be difficult for larger sized fish. The study of total length and body weight of A. fasciatus indicated that the females of each age class and each season were longer (Table 4) and heavier than the males. In addition, the age composition showed that females were dominant in the higher age classes. The strategy of A. fasciatus with respect to its population structure is characteristic of species from unstable and variable environments.

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