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Short communication

Age, growth and mortality of *Atherina boyeri* Risso, 1810 (Pisces: Atherinidae) in the Mesolongi and Etolikon lagoons (W. Greece)

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Abstract

Age, growth and mortality of *Atherina boyeri* (Risso, 1810) from the Mesolongi and Etolikon lagoons were studied. Age determinations based on scale readings show that the population has a 3-year life cycle. Annulus formation took place during February and March each year. A maximum total length of 103 mm was recorded for a 3-year old female. *Atherina boyeri* grows allometrically ($b = 3.15$) and relatively rapidly, achieved the 65.67% of the growth during the first year. The overall sex ratio of males : females was 1 : 1.2, and it varies seasonally depending on the reproductive period. The total mortality rate was $Z = 0.93$/year and the natural mortality rate $M = 0.41$/year. The exploitation rate indicates that the population is slightly overexploited ($E = 0.56$).

Keywords: *Atherina boyeri*; Lagoon; Age; Growth; Life history

1. Introduction

Atherina boyeri (Risso, 1810) is a euryhaline teleost fish which inhabits coastal and estuarine waters, as well as lagoons, salt marshes, shallow brackish water ecosystems, and inland waters. It is common in the Mediterranean and adjacent seas, and is found in the north-east Atlantic from Azores to the north-west coast of Scotland. It is a relatively important commercial fish.

Aspects of life history of *A. boyeri* have been recorded at various locations in the Mediterranean (Kiener and Spillman, 1969; Boscolo, 1970; Kohler, 1976; Castel et al., 1977; Palmer et al., 1979; Marfin, 1982a–c; Palmer and Culley, 1983; Gon and Ben-Tuvia, 1983; Ferrari and Rossi, 1984; Henderson and Bamber, 1986, 1987; Bamber and Henderson, 1988; Fernandez-Delgado et al., 1988; Creech, 1992; Trabelsi et al., 1994; Fouda, 1995).

Annual catches in the Mesolongi and Etolikon lagoons fluctuated wide during the last decade from 10 to 100 tonnes, with an average of 40 tonnes and contributed about 14% to the total fish catch of the two lagoons. Its average price in the Greek market is approximately 3 US$ per kg. The fishing period lasts only a few weeks in February of each year. Purse seines are used in the Etolikon lagoon and beach seines in the Mesolongi lagoon. In the last few years

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the annual catches declined following fish mass mortalities, which occurred in the Etolikon lagoon (Leonardos and Sinis, 1997), and also from improper fisheries management.

In this paper we present information on age, growth, population structure, reproduction, mortality and exploitation rate of *A. boyeri* from the Mesolongi and Etolikon lagoons.

2. Study area

The study was conducted in the Mesolongi and Etolikon lagoonal system (38°15′–38°30′N and 21°05′–21°35′E) (Fig. 1) which is among the largest in the Mediterranean, with a surface area of about 150 km^2. The Etolikon lagoon is of tectonic origin and makes up the northern part of the system and has mean depth of 12 m and maximum of 33 m. The Mesolongi lagoon comprises the central and southern part of the lagoon system and connects to the south with the Patraikos Gulf, which was formed through the silting action of two adjacent rivers; the Acheloos and Evinos. The Mesolongi lagoon has mean 0.5 m and maximum depth of 2 m, respectively.

3. Materials and methods

Samples of *A. boyeri* were obtained at monthly intervals, during the period from April 1989 to June 1990. Samples were collected from a station in the northwest of the Mesolongi lagoon (Fig. 1). A beach seine having mesh size 2.5 mm, length of 15 m, height of 1.5 m at the edges and 2 m in the center, which terminated in a sac with a diameter of 1.5 m and length 3 m, was used.

A sample of 426 fish taken in June 1990, with total length from 13.8 to 103 mm was examined, to study the age, growth and mortality. Furthermore the total length of 1800 specimens was measured to study the length frequency distribution of *A. boyeri*, fish being arranged into size groups with intervals of 2 mm.

Sampling was carried out at the end of each month between 9.00 a.m. and 11.00 a.m. When caught, the fish were preserved in neutralised formalin 4% prior to examination.

To examine the monthly changes in the gonads, the gonadosomatic index (GSI) was calculated for male and female specimens separately, according to the following relationship: GSI = (GW/NW) × 100,

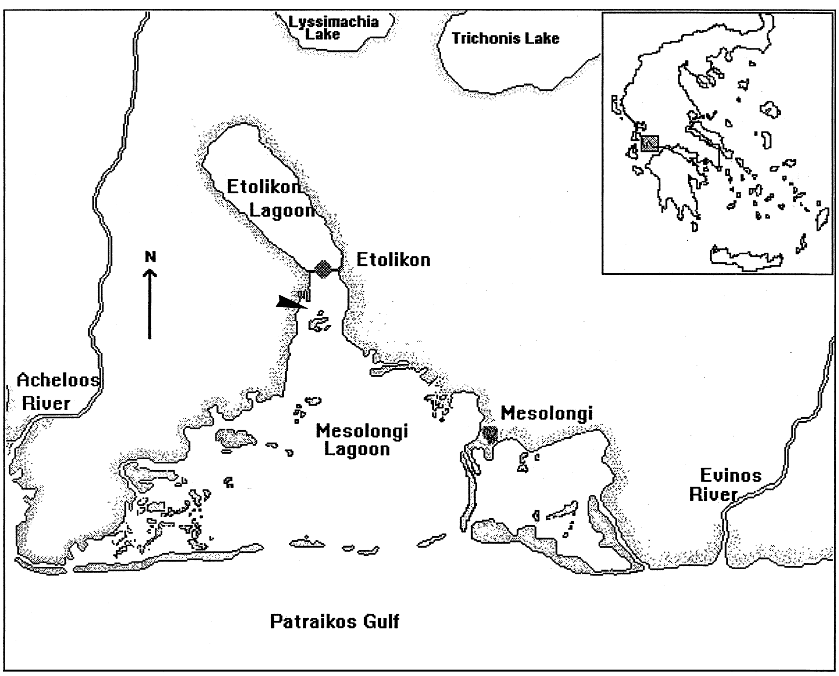

Fig. 1. Map of the Mesolongi and Etolikon lagoons. The arrow head indicates the sampling station.

where GW is the weight of the gonads and NW the body weight (Wooton, 1990). Age was determined from scales, which were taken from the left flank along the line of the silver stripe, between the posterior end of the pectoral fin and the anterior end of the dorsal fin. 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 (Marfin, 1982a).

The relationships: total length–somatic weight and total length–total scale radius were calculated for each sex separately and the slopes were compared using an analysis of covariance (ANCOVA, Tukey-test) (Zar, 1984). The back-calculated total lengths were determined using the equation: $\mathrm{TL}_n = a + (\mathrm{TL} - a) \times R_n/R$ (where TL_n is the length of the fish when annulus "n" was formed, TL the length of the fish when the scale sample was obtained, R_n the radius of annulus "n". R the total scale radius, and a the intercept on the length axis, of the linear regression relationship between total length and total scale radius) (Bagenal and Tesch, 1978) and were tested for differences between the sexes. The von Bertalanffy growth equation was fitted to mean back-calculated lengths at age using the method of Ford–Walford (Everhart and Youngs, 1975).

The sex ratio was estimated in a sample of 471 fish, which were collected in April 1990 during the reproductive period. Also sex ratio was estimated in 414 fish which were collected in eight monthly samples.

Total mortality rate was estimated for each sex separately using the cumulated catch curves (Jones and Van Zalinge, 1981)

$$\log_e(N_c) = a + Z/k \log_e(L_\infty - L)$$

and was tested for differences in slopes (Z/k) between sexes using ANCOVA. N_c is the cumulative number of fish of length L and above, L_∞ and k are the parameters of the von Bertalanffy equation, Z/k the slope of the curve. For the estimation of the total mortality (Z) catch curves were developed from the length frequency distribution. Natural mortality (M) was estimated using the empirical formula of Pauly (1980):

$$\log(M) = -0.0066 - 0.279\log(L_\infty) + 0.6543\log(k) + 0.4634\log(T).$$

where L_∞ and k are the parameters derived from the von Bertalanffy equation, T the mean environmental temperature which during this study was 19.77°C. Exploitation rate was estimated using the equation: $E = F/(F + M)$ (Ricker, 1975), where F is the fishing mortality and M the natural mortality.

4. Results

4.1. Age

Scale readings showed four age classes of which two (0 and I) were dominated (Table 1). Maximum lengths observed were 103 mm female and 83.1 mm male, both 3 years old. One annulus was formed per year. The highest percentage of individuals with an annulus at the edge of the scale was found during February–March and occasionally in January and April, suggesting annulus formation near that period; thus 1 March was considered as the birth date. To compare the results of age determination using scale readings with those of size composition, the fish were classified into size groups with a length of 2 mm (Fig. 3). Young of the year recruitment to the sampled population took place from May to October (Fig. 3) since *A. boyeri* is a multi-spawner.

4.2. Growth

The slopes of the logarithmic equations between somatic weight (NW) and total length (TL) of the fish examined using ANCOVA, showed that there was no significant difference between the sexes (females: $\mathrm{NW} = 4.07 \times 10^{-3}\,\mathrm{TL}^{3.16}, N = 265, R^2 = 0.98$; males: $\mathrm{NW} = 4.26 \times 10^{-3}\,\mathrm{TL}^{3.11}$, $N = 161$, $R^2 = 0.95$; ANCOVA $F = 0.598$, $\mathrm{df} = 423$, $P = 0.227$). Hence the equation derived from the combined sexes was $\mathrm{NW} = 4.168 \times 10^{-3}\,\mathrm{TL}^{3.15}, N = 426, R^2 = 0.95$. The confidence limits of the slope of the regression for the sexes combined was 3.09–3.21, displaying that somatic weight grew allometric with size.

The relationship between total length (TL) and total scale radius (R) was studied for each sex separately. Linear regression gave the best fit. The slopes of the equations indicated that there were no significant differences between sexes (female: $\mathrm{TL} = 13.52 + 64.85R$, $N = 149$, $R^2 = 0.87$; male: $\mathrm{TL} = 12.70 + 63.83R$, $N = 86$, $R^2 = 0.96$; ANCOVA $F = 0.081$, $\mathrm{df} = 232$, $P = 0.713$). Hence the equation derived

Table 1
Size and age composition of males and females of Atherina boyeri from Mesolongi and Etolikon Lagoons. Sample was taken in June 1990

Total length class (mm)	Number of fish per age and sex									
	Male					Female				
	0+	1+	2+	3+	Total	0+	1+	2+	3+	Total
10–12										
12–14	1				1					
14–16										
16–18										
18–20	1				1	1				1
20–22	2				2					
22–24	2				2	1				1
24–26	5				5	1				1
26–28	5				5	2				2
28–30	2	2			4	2	2			4
30–32	2	1			3	5				5
32–34	6				6	4				4
34–36	5	1			6	4	1			5
36–38	3	3			6	4	1			5
38–40	9	2			11	5				5
40–42	8	1			9	5	1			6
42–44	12	3			15	10				10
44–46	16	3			19	11	1			12
46–48	11	2			13	17	1			18
48–50	5	11	1		17	6	9			15
50–52	3	10			13	5	7			12
52–54	5	7			12	2	9			11
54–56	1	6			7		2	2		4
56–58		6	1		7	2	12	2		16
58–60		3			3		7	6		13
60–62		3			3		5	3	1	9
62–64		1	2	1	4		1	5		6
64–66			3	1	4		1	8		9
66–68				1	1		1	7	1	9
68–70			2		2			5		5
70–72				2	2		2	5		7
72–74			1	1	2			6	3	9
74–76				1	1			3	1	4
76–78				1	1			2	2	4
78–80								1	4	5
80–82			1		1				3	3
82–84				1	1				1	1
84–86				1	1				4	4
86–88									2	2
88–90									2	2
90–92									2	2
92–94									3	3
94–96										
96–98										
98–100									1	1
100–102										
102–104									1	1
104–106										
Total	104	65	11	9	190	87	63	55	25	236

Table 2
Back-calculated total lengths (mm) at age of both sexes of *Atherina boyeri* from Mesolongi and Etolikon lagoons[a]

Age (years)	MTLC (95% c.l. of MTLC)	N	Age (years)		
			1	2	3
0+	42.40 (41.49–43.30)	319			
1+	55.53 (54.57–56.49)	66	49.49 (48.75–50.23)		
2+	69.39 (68.34–70.43)	34	48.44 (47.67–49.20)	63.36 (62.41–64.30)	
3+	83.40 (80.56–86.24)	7	49.15 (47.42–50.88)	63.90 (62.15–65.65)	74.75 (72.57–76.93)
All classes total length (95% c.i. of total length)			49.09 (48.57–49.61)	63.47 (62.63–64.30)	74.75 (72.57–76.93)
Average annual increments of BCTL			49.09	14.88	10.86
% of average annual increments of BCTL			65.67	19.91	14.42
N		426	66	34	7

[a] MTLC: mean total length at capture; *N*: number of fish; BCTL: back-calculated total lengths.

from the combined sexes was $TL = 12.26 + 65.82R$ ($N = 235$, $R^2 = 0.91$). Intercept "*a*" from the linear equation of combined sexes was used to back-calculate lengths at age (Table 2).

The mean back-calculated total lengths of each age group were 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 (Table 2). Mean back-calculated total lengths at age indicated rapid growth in the first year of life with the fish attaining almost 65.67% of their maximum adult size during this period and a sharp decline in growth during the second year (19.91%). A steady, less rapid decline in mean calculated increments occurred during the third year (14.42%) (Table 2). Mean total lengths at capture and back-calculated to time of annulus formation for assigned ages closely agreed with length frequencies, which supports annual mark validity.

The parameters of the von Bertalanffy growth curves fitted to mean back-calculated total lengths at age for each sex separately were estimated as $L_\infty = 74.97$ mm, $k = 0.67$/year and $t_0 = -0.46$ years, yielding $Lt = 74.97 \times [1 - e^{-0.67(t + 0.46)}]$ for males and as $L_\infty = 119.94$ mm, $k = 0.23$/year and $t_0 = -1.37$ year, yielding $Lt = 119.94 \times [1 - e^{-0.23(t + 1.37)}]$ for females. The parameters derived from the combined sexes were $L_\infty = 115.79$ mm, $k = 0.24$/year and $t_0 = -1.27$ years, yielding $Lt = 115.79 \times [1 - e^{-0.24(t + 1.27)}]$. The theoretical asymptotic total length, 115.79 mm, is realistic since the largest specimen caught during this study has a total length 103 mm.

4.3. GSI

The gonads in both sexes were present as a single gland. The testis was white in colour, the ovary was white when immature and covered with peritoneum as it matured, then darkened to black. *A. boyeri* were mature at the end of their first year at a mean total length of 34 mm, although a number of new-born individuals of both sexes were found to have well developed gonads. These were individuals, which were born at the beginning of the reproductive period and reached sexual maturity towards the end. The GSI values increased during January and February, a rapid increase in the index occurred from March, maximum indices were recorded in May. The monthly mean GSI values in May were 13% and 8.2% for female and male specimens, respectively. From the examination of GSI values it seems that the reproductive period lasts from the start of March to end of July.

4.4. Sex ratio

The overall sex ratio of males : females was 1 : 1.2 ($x^2 = 3.9$, which is not significantly different from 1 : 1 at $P < 0.05$). Also the ratio varied seasonally and demonstrated large differences in values. Males dominated in February and March and females from April to January (Fig. 4). Before the reproductive period in March, the sex ratio was males : females 1 : 0.83, during the reproductive period the proportion of females in the population was increased, 1 : 1.17 in April, 1 : 2.83 in June and peaked in October with the ratio reaching 1 : 3.14 males : females. From Novem-

Table 3

Age structure, parameters of the length–weight relationship (*a*, *b*) and growth (L_∞, *k*, t_0) of the *Atherina boyeri* in this study and in studies by other authors

Authors	Study area	Maximum age (years)	*N*	*a*	*b*	L_∞ (mm)	*K* (per year)	t_0 (years)
Kohler (1976)[a]	Prevost Lagoon, France		1400	0.48	3.2			
Castel et al. (1977)[a]	Arcachon Bay, France	2	3409	4.58×10^{-3}–8.24×10^{-3}	2.89–3.21			
Palmer and Culley (1983)[b]	Oldbury-upon-Severn, England	3	67	2.5×10^{-6}	3.36			
Gon and Ben-Tuvia (1983)[b]	Bardawil Lagoon, Sinai	1–2	42	13.7×10^{-6}	2.93			
Henderson and Bamber (1987)[b]	English Channel populations	4				138	0.7	
Fernandez-Delgado et al. (1988)[c]	Guadalquivir River, Spain	2	2510	6.97×10^{-3}–7.83×10^{-3}	2.98–3.15			
Creech (1992)[b]	Aberthaw Lagoon S. Wales	2	329	3.5×10^{-6}	3.27	92		
Leonardos et al. (1993)[a]	Trichonis lake W. Greece	4	572	3.8×10^{-6}	3.45	123.24	0.374	0.0179
Stoumboudi et al. (1997)[a]	Trichonis lake W. Greece		2543	3×10^{-6}	3.21			
Present study[a]	Mesolongi and Etolikon Lagoons W. Greece	3	4269	4.168×10^{-3}	3.15	115.79	0.24	−1.27

[a] Using total length.

[b] Using standard length.

[c] Using fork length.

ber to March the population shifted continually from more females to slightly more males (Fig. 4).

4.5. Mortality

The fishing net used was capable of catching *A. boyeri* with a total length greater than 10 mm. Total mortality rates were estimated using the cumulated catch curves. The slopes of the resultant curves (*Z*/*k*) did not differ significantly between sexes (ANCOVA, $P < 0.05$) and hence the total mortality was estimated from the two sexes combined. The total mortality corresponding to the slope of the curve was found to be $Z = 0.93$/year. The natural mortality (*M*) was found to be $M = 0.41$/year. Then the calculation of fishing mortality gave $F = 0.52$/year. The exploitation rate was computed as $E = 0.56$, indicating that the fishing pressure exerted on the *A. boyeri* in the Mesolongi lagoon, was rather high.

5. Discussion

The values of *b* in the equation relating total length and somatic weight for males, females and both sexes differ significantly from three, and therefore show an allometric increase (Ricker, 1975). The values of the exponent "*b*" differ from the values determined in other locations and was relatively smaller (Table 3).

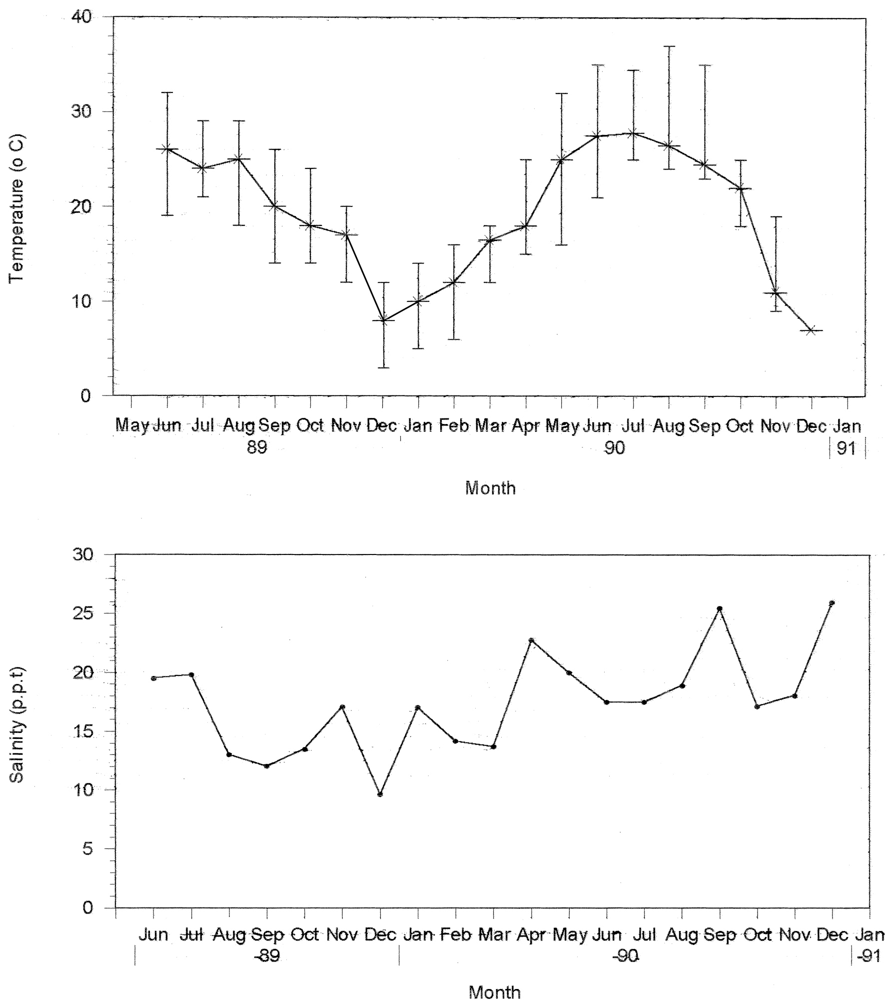

Fig. 2. Monthly variations of the mean water temperature and salinity at the sampling station in the Mesolongi lagoon.

One of the characteristics of life history of *A. boyeri* is the short lifespan. There are four age classes of *A. boyeri* in the Mesolongi and Etolikon lagoons, compared with five age classes in the Trichonis lake (Leonardos et al., 1993). The four age classes life cycle exhibited by *A. boyeri* in Mesolongi and Etolikon Lagoons concurs with the expectations of Palmer and Culley (1983), who proposed four age classes structure, while there is a three age classes structure in Aberthaw Lagoon (Creech, 1992) and in Arcachon Bay (Kiener and Spillman, 1969; Castel et al., 1977). Henderson and Bamber (1987) found that there are five age classes in some populations of *A. boyeri* in English waters (Table 3). Annulus formation was first evident in February and March and was present in all specimens caught in April, whereas in a northern population in Aberthaw Lagoon in South Wales, studied by Creech (1992), annulus formation was present in April and May. The formation of the annual ring appears to occur after the period in which the lowest water temperature is observed (Fig. 2). Leonardos et al. (1996) found that in the Mesolongi and Etolikon Lagoons *Aphanius fasciatus* form their annual ring the same period as *A. boyeri*. Weatherley (1987) reports that the specific physiological mechanisms that cause the formation of annual rings are poorly understood, most of the factors are low or high temperature, reduced food availability or consumption, and reproductive activity. It seems that in the present study, however formation of the annual ring, is associated primarily with temperature (Fig. 2) and food intake. By comparing the data of size composition (Fig. 3) with the results of scale reading it was found that in most cases the method of length frequency gave correct results.

The rapid early growth rate through age one was typical of most Atherinids (Boscolo, 1970; Turnpenny et al., 1981; Palmer and Culley, 1983; Henderson and Bamber, 1987; Fernandez-Delgado et al., 1988; Creech, 1992). The estimated L_∞ (115.79 mm) derived from the Ford–Walford method was in close agreement with the maximum total length recorded ($L_{max} = 103.0$ mm) and within the range of the results of previous investigations. The overall growth rate indicated by the von Bertalanffy growth coefficient ($k = 0.24$/year) was slower than for other studies (Table 3).

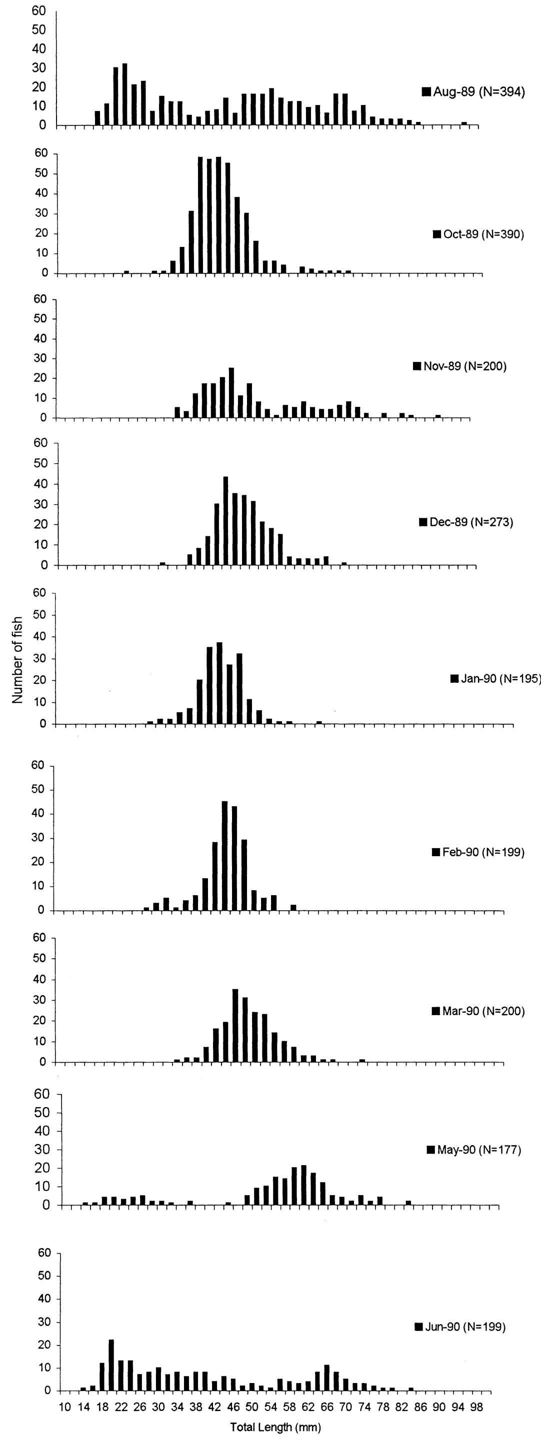

Fig. 3. Length frequency distribution of *Atherina boyeri* from Mesolongi and Etolikon lagoons.

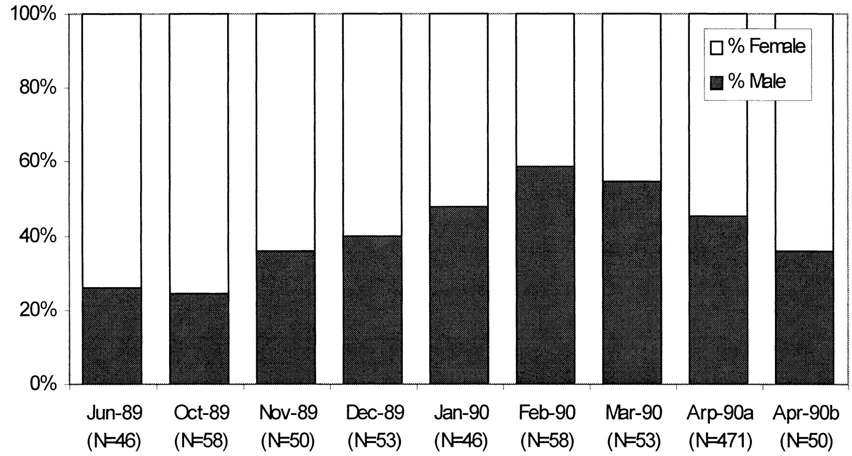

Fig. 4. Proportion of male and female *Atherina boyeri* in monthly samples from the Mesolongi and Etolikon lagoons.

Part of the life history strategy of *A. boyeri* is the extended duration of the reproductive period. This is evident from the duration of the high GSI values showing that the reproductive period has a duration of about five months. GSI were relatively low since *A. boyeri* is a batch spawner. *A. boyeri*in the Mesolongi and Etolikon lagoons first reproduces after completion of the first year of life, although a number of new-born individuals of both sexes were found to have well developed gonads. These were individuals, which were born at the beginning of the reproductive period and reached sexual maturity towards the end. Gon and Ben-Tuvia (1983) reports that populations of *A. boyeri* from the Mediterranean coast of the Sinai peninsula, reach sexual maturity at an age of 2–3 months. Reproduction in the age class 0+ has also been observed in populations of *A. fasciatus* in the Mesolongi and Etolikon lagoons, where individuals form gonads and reproduce few months after hatching (Leonardos and Sinis, 1998). Reproductive strategy of species which live in unstable and unpredictable habitats, includes early sexual maturation, batch spawning and extended spawning season.

Post-larvae were abundant in the lagoon from May. A minimum total length of 14 mm was recorded from the samples. Henderson et al. (1988) report that yolked post-larvae has a standard length 6.5–7.5 mm, the post-larvae developed rapidly to the full external adult morphology at 24 mm within 2 months. Creech (1992) found in the middle of June post-larvae having standard length 5.8 mm.

The proportion of males and females of *A. boyeri* in the population appears to depend on temporal factors, such as the reproduction period. The almost equal ratio of males to females at relatively small sizes indicates that equal numbers of the two sexes are born and enter the population, while an unequal sex ratio during the reproductive period indicates that during the spawning season more females appeared, than males (Fig. 4). Also Fernandez-Delgado et al. (1988) and Creech (1992) observed variations in the sex ratio during the pre-reproductive or reproductive period and attribute this to the formation of unequally sexed shoals as a result of small scale migrations made by the individuals of the stock.

A. boyeri has commercial value due to its abundance and its relative easiness of catch. Exploitation rate (*E*) shows slightly overexploitation population. One of the characteristics of the biological strategy of *A. boyeri* is the short life span and the high mortality rates of the mature fish especially after the reproductive period is expected. The reproductive period lasts from the start of March to end of July. During the autumn in the Etolikon lagoon often occurs fish mass mortality phenomena due to the upwelling of oxygen depleted depth water in combination with the presence of hydrogen sulphide (Leonardos and Sinis, 1997) which cause the loss of the large proportion of fish populations. The fisheries strategy should be planned so that the fishing period follows the reproductive period and comes before the mass mortality phenomena, so that many of the fish will be caught before they died due to fish mass mortality phenomena.

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