# INFLUENCE OF ENVIRONMENTAL FACTORS ON THE POPULATION DYNAMICS OF APHANIUS FASCIATUS (NARDO, 1827) (PISCES: CYPRINODONTIDAE) IN THE LAGOONS MESSOLONGI AND ETOLIKON (W. GREECE) 

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#### Abstract

Age frequency, growth, and mortality of Aphanius fasciatus were studied using 1084 specimens collected from three locations in the Messolongi and Etolikon lagoons. The three sampling stations, Rebakia, Astrovitsa, and Alykes, differed in terms of physicochemical parameters of the water, composition of the bottom, depth of the water, and presence of predators. The caudal fin was longer in males than females. Specimens from the station with a high salinity regime (Alykes) had longer caudal fins than those from the other stations. The region with rich vegetation of shallow waters (Rebakia station) had the highest number of age classes. The Rebakia specimens were also heavier than those of the other stations. At Alykes, females were heavier than males for fish of the same length. Females, and specimens from Rebakia had longer observed and back-calculated total lengths at each age class, than males and specimens from Astrovitsa (area with deep waters and fish predators present) and Alykes, respectively. The values of total mortality were higher for males than females. At Rebakia the mortality rate of both sexes was lower than at Astrovitsa and Alykes.


## INTRODUCTION

Aphanius fasciatus (Nardo, 1827) is commonly known in Greece as zabarola. It is a 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. Populations live in geographically isolated aquatic habitats and under conditions not considered to be optimal, in terms of salinity and the content of various ions. It is found in the central and eastern coastal zone of the Mediterranean Sea (Corsica, Italy, former Yugoslavia, Greece, Cyprus, Turkey, Israel, Egypt-including the Suez Canal, Algeria, and Tunisia). According to Kiener and Schachter (1974) there

[^0]are four representatives of the genus Aphanius in the Mediterranean. These are Aphanius fasciatus (Nardo, 1827), A. iberus (Cuv, and Val., 1846), A. dispar (Ruppell, 1828), and A. mento (Heckel, 1843) which is a freshwater fish. Hybrids between these species have also been reported (Goren and Rychwalski, 1978; Villwock, 1985).

The morphometric characteristics, polymorphism, and reproduction of Aphanius fasciatus have been studied (Boumaiza et al., 1979). However to date, neither a complete study of the species, nor a comparative study of the biology of the species in relation to different environmental conditions, has been carried out. Thus, in this study, information on the age, growth, and mortality of A. fasciatus is presented, for individuals which were collected from three areas in the Messolongi and Etolikon lagoons. The prevailing environmental conditions in the habitat, such as salinity, depth, and temperature of the water, and vegetation cover, were measured in order to evaluate their influence on the biological characteristics of the fish species examined.

## STUDY AREA

The interconnecting lagoons of Messolongi, Etolikon, and Klisova ( $38^{\circ} 18^{\prime} 36^{\prime \prime} \mathrm{N}$, $21^{\circ} 31^{\prime} 00^{\prime \prime} \mathrm{E}$ ) in Western Greece, are among the largest in the Mediterranean and have a total area of about $150 \mathrm{~km}^{2}$. The lagoons have formed through the siltation of two rivers, the Acheloos and Evinos. The Etolikon Lagoon makes up the northern part of the ecosystem, while the Messolongi Lagoon the central and southern part. The lagoons are connected to the south to the Patraikos Gulf (Fig. 1).


Fig. 1. Map of the Messolongi and Etolikon lagoons showing the locations of the sampling stations.

## MATERIALS AND METHODS

Sampling was carried out monthly at three different stations in the Messolongi and Etolikon lagoons (Fig. 1). The specimens which were used in the study of age, growth, and mortality came from a sample catch made on 24 June 1990. Specimens used for the determination of the time of formation of the annual ring came from monthly samples taken from April 1989 until January 1991. Sampling was carried out at each of the three sampling stations at the end of each month between 9.00 and 11.00 am . The values of the water and air temperature, salinity, dissolved oxygen, and pH were recorded during each sampling. Maximum-minimum thermometers were placed at each sampling station to measure the range of temperatures encountered during the course of each month. Samples were collected using seine nets with a mesh size of 2.5 mm , a length of 15 m , and a 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 of 3 m . The design of the net was based on those used by local fishermen for catching fish of small size. The net was dragged by two people over exactly the same distance at each of the three sampling stations. Caught fish were rinsed in clean freshwater and placed immediately in $4 \%$ formalin, where they remained until examination. A total of 1,084 specimens from the three sampling stations were studied. These ranged in length from 21.13 to 70.63 mm .

The total and the standard body length were measured using a digital micrometer with an accuracy of 0.01 mm . The standard length was the distance between the tip of the upper jaw and the posterior end of the hypoural bone (Anderson and Gutreuter, 1983). After the removal of the intestines and the gonads, the somatic weight was recorded using an electronic balance with an accuracy of 0.1 mg . The sex was determined from the external characteristics but also by examination of the gonads.

Age was determined from the scales, since it was more easily carried out than from the otoliths, and the observations were more reliable because formalin alters the structure of the otolith (Bagenal and Tesch, 1978).

Scales were 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 stereoscope with transmitted and reflected light. 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).

The results from the determination of age were compared with other available biological data such as distance of the scale margin, size composition, and monthly observations for the determination of age groups and the time of formation of annual rings. 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 $\left(\mathrm{R}_{\mathrm{n}}\right)$.

The caudal length was taken as the difference between the total length (TL) and the standard body length (SL) of the fish (TL - SL) 100 / TL (Boumaiza, 1980; Meng and Stocker, 1984) and was tested for differences between the sexes ( $t$-test) and between the sampling stations (ANOVA). The relationships: total length-somatic weight (W) and total length-scale radius were determined for each sex and each sampling station
separately, and were tested statistically for differences between the regression coefficients of the sexes and the sampling stations (ANCOVA). Differences were deduced using paired comparisons of slopes-Tukey test (Zar, 1984).

The back-calculated total lengths were determined using the equation of Fraser and Lee (Bagenal and Tesch, 1978): $\mathrm{TL}_{\mathrm{n}}=\mathrm{a}+(\mathrm{TL}-\mathrm{a}) \mathrm{R}_{\mathrm{n}} / \mathrm{R}$, (where $\mathrm{TL}_{\mathrm{n}}=$ length of the fish when annulus " $n$ " was formed, $\mathrm{TL}=$ length of the fish when the scale sample was obtained, $\mathrm{R}_{\mathrm{n}}=$ radius of annulus " n ", $\mathrm{R}=$ total scale radius, $\mathrm{a}=$ intercept on the length axis, of the linear regression relationship between total length and scale radius) and was tested for differences between the sexes and sampling stations.

Parameters of the von Bertalanffy equation were determined using the method of Ford-Waldford using the back-calculated total lengths of each age-group (Everhart and Young, 1975).

Total instantaneous mortality ( $Z$ ) was calculated for each sex and each sampling station using catch curves linearized by the equation $\log _{e} N=\alpha-Z t$, where $N$ is the population number of each age-class $t$ (Gulland, 1983). All of the mortality slopes were examined using analysis of covariance for differences between the sexes at each sampling station and between the sampling stations. Differences between the slopes were found using the Tukey test. Survival rates (S) were estimated from the equation $\mathrm{S}=\mathrm{e}^{-\mathrm{z}}$.

The relationship between the biological and physicochemical parameters of the water and sampling stations was studied using Principal Components Analysis (PCA) (Digby and Kempton, 1987).

## RESULTS

## PHYSICOCHEMICAL PARAMETERS

The Rebakia station (RE) had an average depth of 0.8 m and the bottom was covered with rich vegetation. The temperature ranged annually from $7.0-27.8^{\circ} \mathrm{C}$ with a mean value of $19.7^{\circ} \mathrm{C}$. Salinity ranged from $14.0-23.5 \mathrm{ppt}$ with a mean annual value of 17.6 ppt (Fig. 2). The Astrovitsa station (AS) was chosen in a quite deep (as far as lagoons are concerned) region and had an average depth of 12 m and maximum depth of 29 m . Sampling was carried out at a depth of $1.5-2.0 \mathrm{~m}$. The lagoon bed was sandy. The temperature and salinity ranged annually from $8.0-28.7^{\circ} \mathrm{C}$ and $10-22 \mathrm{ppt}$, with mean values of $19.8^{\circ} \mathrm{C}$ and 14 ppt , respectively. The Alykes station (AL) was located in the first salt pans of the Messolongi salt works. Water from this location is supplied to the main salt pans for the production of salt. The average depth of the water was less than 0.5 m , the bottom was covered with large quantities of mud, and the vegetation was minimal. The temperature and salinity ranged annually from $6-39^{\circ} \mathrm{C}$ and $19-80 \mathrm{ppt}$, with mean values of $23.1^{\circ} \mathrm{C}$ and 48.8 ppt , respectively.

## AGE

The age composition, which was determined using scale readings for the three stations separately, was found to differ between the sexes and between the stations


Fig. 2. Monthly variations of the mean water temperature and salinity at the sampling stations.
(Table 1). At AS, young individuals were dominant. At this station the longest female caught during the course of the study had a length of 70.63 mm and an age of 6+. At RE, $9.7 \%$ of the individuals had an age greater than 4 years; at AS, $1.6 \%$; while at AL, only $0.9 \%$ were older than 4 years. In order to compare the results of age determination using scale readings with those of size composition, the fish in the sample were classified into size groups with a length of 2 mm (Fig. 3). There was agreement between the length at catch and the frequency of sizes.

The highest percentage of individuals with an annulus at the edge of the scale were found during February (Fig. 4). Therefore, it can be presumed that Aphanius fasciatus forms its annual ring in February.

## GROWTH

The size of the caudal fin was found to differ significantly ( $t$-test) between the sexes (Table 2). The males had longer caudal fins than the females at all the stations (RE: $17.93>17.29$, AS: $18.16>16.26$, AL: $19.05>18.04$ ). The length of the caudal fin of individuals of the same sex were found to differ significantly (ANOVA) between the sampling stations. Individuals of boths sexes from station AL had longer caudal fins than those from stations RE and AS (female: $18.04>17.29>16.96$, male: $19.05>17.93$ $=18.16$ ).

The relationship between TL and W of the fish was examined for each sex separately and for each sampling station (Table 3). The slopes (b) of the logarithmic equations were examined using ANCOVA, which showed that there was no significant difference between the sexes at stations RE and AS (RE: $3.44=3.40$, AS: $3.22=3.26$ ), while at

Table 1
Age, size (mm), and sex ( $\mathrm{F}=$ female, $\mathrm{M}=$ male) composition of Aphanius fasciatus populations at sampling stations Rebakia, Astrovitsa, and Alykes, 24 June 1990

|  | Rebakia |  |  |  |  |  |  |  |  |  | Astrovitsa |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0+ | $1+$ | $2+$ | $3+$ |  | 4+ | 5+ |  | $6+$ |  | 0+ | 1+ | $2+$ |  | + | 4+ | $5+$ | $6+$ |
| TL | F M | F M | F M | F M | F | M | F M |  | M | Total | F M | F M | F M | F | M | F M | F M | F M Total |
| 20-22 | 1 |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  |  |  |  |
| 22-24 | 62 |  |  |  |  |  |  |  |  | 8 | 1 |  |  |  |  |  |  | 1 |
| 24-26 | 152 |  |  |  |  |  |  |  |  | 17 | 4 |  |  |  |  |  |  | 4 |
| 26-28 | 102 |  |  |  |  |  |  |  |  | 12 | 216 |  |  |  |  |  |  | 18 |
| 28-30 | 112 | 1 |  |  |  |  |  |  |  | 14 | 10 | 7 |  |  |  |  |  | 17 |
| 30-32 | 112 | 58 |  |  |  |  |  |  |  | 26 | 3 | 16 |  |  |  |  |  | 10 |
| 32-34 | 4 | 614 |  |  |  |  |  |  |  | 24 |  | 218 |  |  |  |  |  | 20 |
| 34-36 |  | 1118 |  |  |  |  |  |  |  | 29 |  | 321 |  |  |  |  |  | 24 |
| 36-38 |  | 318 |  |  |  |  |  |  |  | 21 |  | 320 | 2 |  |  |  |  | 25 |
| 38-40 |  | 59 | 14 |  |  |  |  |  |  | 19 |  | 314 | 23 |  |  |  |  | 22 |
| 40-42 |  | 1310 | 6 |  |  |  |  |  |  | 29 |  | 15 | 26 |  |  |  |  | 14 |
| 42-44 |  | 127 | 213 |  |  |  |  |  |  | 34 |  | 3 | 139 |  |  |  |  | 25 |
| 44-46 |  | 61 | 89 | 1 |  |  |  |  |  | 25 |  |  | 137 |  |  |  |  | 20 |
| 46-48 |  | 32 | 1012 | 3 |  |  |  |  |  | 30 |  |  | 131 | 1 |  |  |  | 15 |
| 48-50 |  |  | 105 | 43 |  |  |  |  |  | 22 |  |  | 21 | 5 | 2 |  |  | 28 |
| 50-52 |  |  | 152 | 38 |  |  |  |  |  | 28 |  |  | 17 | 8 |  |  |  | 25 |
| 52-54 |  |  | 72 | 82 | 1 |  |  |  |  | 20 |  |  | 1 | 12 |  |  |  | 13 |
| 54-56 |  |  | 11 | 94 | 2 |  |  |  |  | 17 |  |  |  | 8 |  | 1 |  | 9 |
| 56-58 |  |  |  | 41 | 3 | 1 |  |  |  | 9 |  |  |  | 2 |  | 2 |  | 4 |
| 58-60 |  |  |  | 72 | 5 |  | 1 |  |  | 15 |  |  |  |  |  |  |  | 0 |
| 60-62 |  |  |  |  | 8 | 1 | 1 |  |  | 10 |  |  |  |  |  |  |  | 1 |
| 62-64 |  |  |  |  | 5 |  | 4 |  |  | 9 |  |  |  |  |  |  |  |  |
| 64-66 |  |  |  |  | 2 |  | 1 |  |  | 3 |  |  |  |  |  |  |  |  |
| 66-68 |  |  |  |  |  |  | 5 |  | 1 | 6 |  |  |  |  |  |  |  |  |
| 68-70 |  |  |  |  |  |  |  | 1 |  | 1 |  |  |  |  |  |  |  |  |
| 70-72 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 11 |
| Total | 5810 | 6587 | 5454 | 3524 | 26 | 2 | 12 | 1 | 1 | 429 | 234 | 1394 | 8228 | 36 | 2 | 3 | 1 | 296 |


| Alykes |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0+ | 1+ | 2+ | $3+$ | 4+ |  |
| TL | F M | F M | F M | F M | F M | Total |
| 20-22 | 2 |  |  |  |  | 2 |
| 22-24 | 11 |  |  |  |  | 2 |
| 24-26 | 1 |  |  |  |  | 1 |
| 26-28 | 21 |  |  |  |  | 3 |
| 28-30 | 22 | 14 |  |  |  | 9 |
| 30-32 | 25 | 8 |  |  |  | 15 |
| 32-34 | 1 | 314 |  |  |  | 18 |
| 34-36 |  | 1316 |  |  |  | 29 |
| 36-38 |  | 1812 | 2 |  |  | 32 |
| 38-40 |  | 1510 |  |  |  | 27 |
| 40-42 |  | 64 | 43 |  |  | 17 |
| 42-44 |  | 95 | 6 |  |  | 20 |
| 44-46 |  | 63 |  |  |  | 13 |
| 46-48 |  |  | 52 |  |  | 7 |
| 48-50 |  |  | 32 | 1 |  | 6 |
| 50-52 |  |  | 2 | 1 |  | 3 |
| 52-54 |  |  |  | 6 |  | 8 |
| 54-56 |  |  | 1 | 21 |  | 4 |
| 56-58 |  |  |  | 2 | 1 | 3 |
| 58-60 |  |  |  | 1 |  | , |
| 60-62 |  |  |  |  | 1 | 1 |
| 62-64 |  |  |  |  |  |  |
| 64-66 |  |  |  |  |  |  |
| 66-68 |  |  |  |  |  |  |
| 68-70 |  |  |  |  |  |  |
| 70-72 |  |  |  |  |  |  |
| Total | 911 | 7176 | 2612 | 113 |  | 221 |



Fig. 3. Length frequency distribution of male and female Aphanius fasciatus from the three sampling stations, 24 June 1994.


Fig. 4. Monthly change of marginal increment of scales in each age class of Aphanius fasciatus from Rebakia station.
station AL the value of $b$ for the females was statistically greater than that for the males (AL: $3.42>3.11$ ). In addition, there were significant differences between individuals of the same sex from the three stations. Females from station RE and AL had higher values of $b$ than those from station $\operatorname{AS}(3.44=3.42>3.22$, respectively). Males from station $R E$ had higher values of $b$ than those from stations AS and AL (3.40 > $3.26=3.11$, respectively).

The relationship between TL and R was studied for each sex separately and for each sampling station. Linear regression gave the best fit (Table 4). The slopes of the lines indicated that there were no significant differences between the sexes at any of the sampling stations; however there were significant differences for fish of the same sex between the sampling stations. Females at station AL had larger values of $b$ than those from stations AS and RL ( $32.22>28.41=30.00$, respectively), while the males at station RE had larger values than those at stations AL and AS (31.74>29.44=28.15, respectively) (Table 4).

Intercept a from the linear equations total length-scale radius was incorporated into Fraser and Lee's equation for each case, for the back calculation of total lengths (Tables 5-7). The mean 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 mean back-calculated total lengths differed according to sex and the sampling area (Tables 5-7). For all ages and at all sampling stations where there was a sufficient number of specimens, females were larger than males of the same age group. The size difference was inferred from the non-overlapping confidence limits of the means.

Table 2
Mean values and confidence limits of the relative caudal length of Aphanius fasciarus in relation to the sampling station and sex

| Station | Sex | CF $=\left(\right.$ TL-SL) ${ }^{\text {c }} 100 / \mathrm{TL}$ | 95\% C.L. of CF | N |
| :---: | :---: | :---: | :---: | :---: |
| Rebakia | Female | C.F. $=17.29 \times *$ | 17.15-17.43 | 276 |
|  | Male | C.F. $=17.93 \times$ \& | 17.77-18.09 | 185 |
|  | Total | C.F. $=17.55^{\circ}$ | 17.44-17.66 | 461 |
| Astrovitsa | Female | C.F. $=16.96{ }^{+\prime}$ | 16.77-17.14 | 137 |
|  | Male | C.F. $=18.16^{+*}$ | 17.96-18.36 | 160 |
|  | Total | C.F. $=17.61{ }^{\circ}$ | 17.45-17.76 | 297 |
| Alykes | Female | C.F. $=18.04 * *$ | 17.83-18.25 | 118 |
|  | Male | C.F. $=19.05 *$ * | 18.76-19.33 | 102 |
|  | Total | C.F. $=18.51{ }^{\circ}$ | 18.32-18.64 | 220 |

Comparison of the size of caudal fins between the sexes at each of the sampling stations: ${ }^{\mathrm{x}} t$-test $=5.97, \mathrm{p}<0.001 ;{ }^{+} t$-test $8.87, \mathrm{p}<0.001 ; * t$-test $=5.60, \mathrm{p}<0.001$. Caudal fin sizes differ significantly between males and females.
Comparison of individuals of the same sex between sampling stations: " $\mathrm{F}=30.44, \mathrm{p}<0.001$; ${ }^{\&} \mathrm{~F}=29.08, \mathrm{p}<0.001$. Caudal fin sizes differ significantly between the sampling stations.

Table 3
Parameters of the relationship between weight (W) and length (L) of Aphanius fasciatus with respect to sex and sampling station

| Station | Sex | $\mathrm{W}=\mathrm{a} \mathrm{L}^{\text {b }}$ | 95\% C.L. of b | N | $\mathrm{R}^{2}$ | p |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Rebakia | Female | $W=5.9510^{-3} \mathrm{~L}^{3.44 \times}$ | 3.42-3.46 | 276 | 0.99 | $<0.001$ |
|  | Male | $\mathrm{W}=6.4810^{-3} \mathrm{~L}^{3.40 \mathrm{x}} \mathrm{E}$ | 3.35-3.45 | 185 | 0.99 | <0.001 |
|  | Total | $W=6.1210^{-3} \mathrm{~L}^{3.42 \mathrm{~s}}$ | 3.40-3.45 | 461 | 0.99 | $<0.001$ |
| Astrovitsa | Female | $W=8.2610^{-3} \mathrm{~L}^{3.22+\#}$ | 3.14-3.30 | 137 | 0.97 | <0.001 |
|  | Male | $W=7.5810^{-3} \mathrm{~L}^{3.26+\&}$ | 3.20-3.32 | 160 | 0.98 | <0.001 |
|  | Total | $\mathrm{W}=7.5310^{-3} \mathrm{~L}^{3.27} \mathrm{~s}$ | 3.24-3.30 | 296 | 0.99 | <0.001 |
| Alykes | Female | $W=5.3810^{-3} \mathrm{~L}^{3.42 * m}$ | 3.35-3.49 | 118 | 0.98 | $<0.001$ |
|  | Male | $\mathrm{W}=8.4910^{-3} \mathrm{~L}^{3.11}$ *\& | 2.96-3.25 | 102 | 0.95 | $<0.001$ |
|  | Total | $\mathrm{W}=6.9010^{-3} \mathrm{~L}^{3.26 \$}$ | 3.18-3.32 | 220 | 0.97 | $<0.001$ |

Comparison of the slopes between the sexes at each station separately: ${ }^{\mathrm{x}} \mathrm{F}=1.464, \mathrm{p}=0.227$; ${ }^{+} \mathrm{F}=0.906, \mathrm{p}=0.342 ;{ }^{\circ} \mathrm{F}=16.753, \mathrm{p}<0.001$. The slopes of the equations differ statistically between the sexes only at station (AL) at probability level 0.05 .
Comparison of individuals of the same sex between the sampling stations: " $\mathrm{F}=13.859, \mathrm{p}<0.001$; ${ }^{*} \mathrm{~F}=13.106, \mathrm{p}<0.001$. The slopes of the equations differ significantly at probability level 0.05 . Comparison of all of the individuals between the sampling stations: ${ }^{5} \mathrm{~F}=28.768, \mathrm{p}<0.001$. The slopes of the equations differ significantly at probability level 0.05.

Table 4
Parameters of the relationship total length TL (mm)-scale radius $\mathbf{R}$ (mm) of Aphanius fasciatus with respect to sampling station and sex

| Station | Sex | $\mathrm{TL}=\mathrm{a}+\mathrm{b}^{*} \mathrm{R}$ | 95\% C.L. of b | $\mathrm{R}^{2}$ | N |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Rebakia | Female | $\mathrm{TL}=12.2+30.22 \mathrm{R}^{\text {**** }}$ | 29.55-30.90 | 0.96 | 276 |
|  | Male | $\mathrm{TL}=9.1+31.14 \mathrm{R}^{\mathrm{x} *}$ | 30.14-32.14 | 0.96 | 180 |
|  | Total | $\mathrm{TL}=11.3+30.36 \mathrm{R}^{\circ}$ | 29.73-31.00 | 0.95 | 461 |
| Astrovitsa | Female | $\mathrm{TL}=10.7+28.41 \mathrm{R}^{+\#}$ | 26.98-29.85 | 0.92 | 137 |
|  | Male | $\mathrm{TL}=11.2+28.15 \mathrm{R}+{ }^{+}$ | 27.13-29.17 | 0.95 | 160 |
|  | Total | $\mathrm{TL}=9.1+31.42 \mathrm{R}^{\circ}$ | 30.50-32.35 | 0.94 | 297 |
| Alykes | Female | $\mathrm{TL}=10.6+32.22 \mathrm{R}$ * | 30.50-33.95 | 0.92 | 118 |
|  | Male | $\mathrm{TL}=11.4+29.44 \mathrm{R}$ * | 27.96-30.91 | 0.94 | 102 |
|  | Total | $\mathrm{TL}=9.3+32.10 \mathrm{R}^{\circ}$ | 29.53-33.92 | 0.91 | 220 |
| Total |  | $T L=10.5+30.60 \mathrm{R}$ | 30.10-31.21 | 0.92 | 973 |

Comparison of slopes between the sexes at each sampling station separately: ${ }^{\mathrm{x}} \mathrm{F}=0.107$, $p=0.752 ;{ }^{+} F=0.004, p=0.949 ;{ }^{*} F=2.586, p=0.109$. The slopes of the lines do not differ significantly between them at probability level 0.05 .
Comparison of slopes of individuals of the same sex between the sampling stations: "F $=4.566$, $\mathrm{p}<0.01 ;{ }^{\circledR} \mathrm{F}=8.003, \mathrm{p}<0.001$. The slopes of the lines differ significantly between them at probability level 0.05.
Comparison of slopes of all individuals between the sampling stations: ${ }^{\circ} \mathrm{F}=1.882, \mathrm{p}=0.150$. The slopes of the lines do not differ significantly at probability level 0.05 .

The mean back-calculated total lengths of each age group were used in the von Bertalanffy equation (Table 8). The calculation of growth parameters leads to the evaluation of a series of other parameters of the dynamics of the species, which are related to mortality, and also significant behavioral factors of the fish population.

## MORTALITY

The fishing net used was capable of catching A. fasciatus with a total length greater than 20 mm . Total mortality was determined from the slope of the descending part of the curve for each sex and each sampling station separately. The mortality coefficient did not differ significantly between the sexes at each of the sampling stations; however it did

Table 5
Back-calculated total lengths ( mm ) at different ages of male and female Aphanius fasciatus at the Rebakia station (MTLC $=$ mean total length at capture, $\mathrm{N}=$ number of fish)

Females

| Age |  |  |  |  | Age (years) |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (years) | MTLC | $95 \%$ | C.I. | N | 1 | 2 | 3 | 4 |
| $0+$ | 27.50 | $(26.87-28.12)$ | 73 |  |  |  |  |  |
| $1+$ | 39.14 | $(37.80-40.47)$ | 55 | 32.02 |  |  |  |  |
| $2+$ | 49.21 | $(48.36-50.05)$ | 54 | 34.26 | 43.49 |  |  |  |
| $3+$ | 54.36 | $(53.41-55.20)$ | 38 | 32.25 | 42.84 | 49.64 | 56.43 |  |
| $4+$ | 60.22 | $(58.98-61.45)$ | 22 | 32.28 | 43.44 | 50.70 | 50.82 | 56.88 |
| $5+$ | 64.85 | $(63.55-66.15)$ | 11 | 33.73 | 43.80 | 50.82 | 61.63 |  |
| All classes total length |  | 32.88 | 43.31 | 50.15 | 56.58 | 61.63 |  |  |
| $95 \%$ | C.I. of total length | $(32.45-33.30)$ | $(42.84-43.78)(49.58-50.72)$ | $(55.65-57.50)(60.11-63.14)$ |  |  |  |  |
| N |  |  | 253 | 180 | 125 | 71 | 33 | 11 |

Males

| Age |  |  | Age (years) |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (years) | MTLC | 95\% C.I. | N | 1 | 2 | 3 | 4 | 5 | 6 |
| 0+ | 27.20 | (25.32-29.08) | 10 |  |  |  |  |  |  |
| 1+ | 36.90 | (36.12-37.67) | 76 | 30.51 |  |  |  |  |  |
| $2+$ | 45.41 | (44.48-46.34) | 54 | 30.28 | 39.90 |  |  |  |  |
| $3+$ | 52.15 | (50.58-53.72) | 21 | 30.29 | 40.76 | 47.94 |  |  |  |
| 4+ | 59.22 |  | 2 | 30.86 | 42.35 | 49.33 | 54.77 |  |  |
| $5+$ |  |  | 0 |  |  |  |  |  |  |
| $6+$ | 66.51 |  | 1 | 29.13 | 38.69 | 46.51 | 52.60 | 58.69 | 63.03 |
| All classes total length 95\% C.I. of total length |  |  |  | 30.40 | 40.18 | 48.00 | 54.05 | 58.69 | 63.03 |
|  |  |  | $(29.95-30.84)(39.53-40.82)(46.82-49.17)(51.24-56.85)$ |  |  |  |  |  |  |
| N |  |  | 154 | 78 | 24 | 3 | 3 | 1 | 1 |

Table 6
Back-calculated total lengths (mm) at age of male and female of Aphanius fasciatus at the Astrovitsa station (MTLC = mean total length at capture, $N=$ number of fish)

Females

| Age |  |  | Age (years) |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (years) | MTLC | 95\% C.I. | N | 1 | 2 |  | 3 | 4 | 5 | 6 |
| 0+ | 27.40 | (26.49-28.31) | 2 |  |  |  |  |  |  |  |
| 1+ | 35.81 | (33.74-37.87) | 10 | 29.69 |  |  |  |  |  |  |
| $2+$ | 46.94 | (46.17-47.70) | 70 | 31.96 | 41.83 |  |  |  |  |  |
| 3+ | 52.38 | (51.56-53.20) | 31 | 31.11 | 41.01 |  | 48.13 |  |  |  |
| 4+ | 55.70 | (54.28-57.12) | 2 | 29.16 | 38.48 |  | 45.68 | 51.36 |  |  |
| 5+ | 61.17 |  | 1 | 33.23 | 41.34 |  | 48.55 | 53.06 | 57.56 |  |
| 6+ | 70.63 |  | 1 | 31.02 | 42.19 |  | 52.35 | 60.47 | 64.54 | 68.60 |
| All classes total length 95\% C.I. of total length |  |  |  | 31.49 | 41.52 |  | 48.14 | 54.06 | 61.05 | 68.60 |
|  |  |  | $(31.09-31.89)(41.04-42.00)(47.40-48.88)(49.78-58.33)$ |  |  |  |  |  |  |  |
| N |  |  | 116 | 114 | 104 |  | 34 | 4 | 2 | 1 |
| Males |  |  |  |  |  |  |  |  |  |  |
| Age |  |  |  | Age (years) |  |  |  |  |  |  |
| (years) | MTLC | 95\% C.I. | N | 1 |  | 2 |  |  |  |  |
| 0+ | 27.60 | (27.02-28.18) | 35 |  |  |  |  |  |  |  |
| 1+ | 36.00 | (35.26-36.74) | 84 | 29.60 |  |  |  |  |  |  |
| $2+$ | 42.31 | (41.31-43.31) | 26 | 29.57 |  | 37.94 |  |  |  |  |
| $3+$ | 48.60 |  | 2 | 28.83 |  | 38.01 |  |  |  |  |
| All classes total length |  |  |  | 29.58 |  | 37.95 |  |  |  |  |
| 95\% C.I. of total length |  |  |  | (29.12-30.04) (37.23-38.66) |  |  |  |  |  |  |
| N |  |  | 147 | 112 |  | 28 |  |  |  |  |

differ between the sampling stations (Table 9). At RE the total mortality coefficient was statistically lower for both sexes than those at AS and AL (females: $0.32<1.65=0.93$, males: $0.64<1.92=1.61$ for RE, AS, and AL respectively).

## BIOLOGICAL PARAMETERS-SAMPLING STATIONS

The results of PCA, using parameters given in Tables 2, 3, 4, 8, and 9, indicated that there were three main groups which corresponded to the three sampling stations (Fig. 5). There was a strong correlation between survival ( S ), b of the relationship total lengthsomatic weight, $\mathrm{t}_{\mathrm{o}}^{*}$, and to a lesser extent k , and these parameters characterize males and females at station RE. A strong correlation also existed between $b$ of the relationship

* The $\mathrm{t}_{\mathrm{o}}, \mathrm{k}$, and $\mathrm{L}_{\infty}$ are the parameters of the von Bertalanffy growth equation (Table 8), used as data for principal component analysis. The biological, physiochemical parameters ( $t_{0}, \mathrm{k}, \mathrm{L}_{\infty^{\prime}} \mathrm{S}$, b, T, s, z) and sex per sampling stations (REF, ASF, ASM, ALF, ALM) which are in Fig. 5, represent scores of the principal component analysis.

Table 7
Back-calculated total lengths (mm) at age of male and female Aphanius fasciatus at the Alykes station (MTLC = mean total length at capture, $\mathrm{N}=$ number of fish)

|  | Females |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Age |  |  |  | Age (years) |  |  |
| (years) | MTLC | 95\% C.I. | N | 1 | 2 | 3 |
| 0+ | 28.64 | (26.55-30.73) | 9 |  |  |  |
| 1+ | 38.82 | (37.99-39.65) | 62 | 31.73 |  |  |
| $2+$ | 46.40 | (44.76-48.04) | 20 | 30.46 | 40.56 |  |
| $3+$ | 54.22 | (51.95-56.49) | 6 | 33.24 | 42.38 | 49.26 |
| All classes total length $95 \%$ C.I. of total length |  |  |  | 31.55 | 40.98 | 49.26 |
|  |  |  |  | (31.07-32 | 9.73-42 | .87-51.65) |


| 97 | 88 | 26 | 6 |
| :--- | :--- | :--- | :--- | :--- |

Males

| Age |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| (years) | MTLC | 95\% C.I. | N | 1 | 2 | 3 | 4 |
| 0+ | 28.80 | (25.30-32.29) | 11 |  |  |  |  |
|  | 35.12 | (33.64-36.59) | 58 | 29.42 |  |  |  |
|  | 43.18 | (40.11-46.25) | 10 | 29.96 | 38.68 |  |  |
|  | 50.25 | (49.39-51.10) | 2 | 29.71 | 39.78 | 47.06 |  |
| $4+$ | 57.06 |  | 1 | 29.31 | 40.05 | 47.21 | 53.48 |
| All classes total length S.E. of total length |  |  |  | 29.50 | 38.96 | 47.11 | 53.48 |
|  |  |  | (28.54-30.46) (36.40-40.92) (46.28-47.93) |  |  |  |  |
|  |  |  | 82 | 71 | 13 | 3 | 1 |

Table 8
Estimation of the parameters of the von Bertalanffy equation using the method of Ford-Woldford

| Station | Sex | $L_{\infty}$ | k | $\mathrm{t}_{\text {。 }}$ | $\mathrm{R}^{2}$ | Equation |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Rebakia | Female | 78.62 | 0.245 | -1.20 | 0.99 | $\mathrm{Lt}=78.617\left[1-\mathrm{e}^{0.245(1+1.20)}\right]$ |
|  | Male | 75.68 | 0.246 | -1.19 | 0.99 | $\mathrm{Lt}=75.68\left[1-\mathrm{e}^{0.2466(1+1.19)}\right]$ |
|  | Total | 77.58 | 0.257 | -1.02 | 0.99 | $\mathrm{Lt}=77.584\left[1-\mathrm{e}^{0.257(4+1.02)}\right]$ |
| Astrovitsa | Female | 108.16 | 0.115 | -2.09 | 0.99 | $\mathrm{Lt}=108.16\left[1-\mathrm{e}^{0,115(1+2.09)}\right]$ |
|  | Male | 80.72 | 0.178 | -1.55 | 0.99 | $\mathrm{Lt}=80.716\left[1-\mathrm{e}^{0.178(6+1.55)}\right]$ |
|  | Total | 97.78 | 0.145 | -1.58 | 0.99 | $\mathrm{Lt}=97.778\left[1-\mathrm{e}^{0,145(t+1.58)}\right]$ |
| Alykes | Female | 108.87 | 0.130 | -1.63 | 0.99 | $\mathrm{Lt}=108.87\left[1-\mathrm{e}^{0,130(6+1.63)}\right]$ |
|  | Male | 84.33 | 0.192 | -1.23 | 0.99 | $\mathrm{Lt}=84.33\left[1-\mathrm{e}^{0.192(1+1.23)}\right]$ |
|  | Total | 99.84 | 0.149 | -1.43 | 0.99 | $\mathrm{Lt}=99.84\left[1-\mathrm{e}^{0.1499(1+143)}\right]$ |
| Total |  | 85.69 | 0.204 | -1.18 | 0.99 | $\mathrm{Lt}=85.69\left[1-\mathrm{e}^{0,204(t+1.18)}\right]$ |

Table 9
Estimation of the total instantaneus mortality coefficient ( $Z$ ) and the survival rate ( $\$$ ) of Aphanius fasciatus by least-squares regression of cutch curves

| Station | Sex | $\mathrm{Ln}(\mathrm{N})=\mathrm{a}-\mathrm{Zt}$ | Z | S | N | $\mathrm{R}^{2}$ | p |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Rebakia | Female | $\operatorname{Ln}(\mathrm{N})=4.72-0.32 \mathrm{t}^{\text {x* }}$ | 0.32 | 0.726 | 4 | 0.94 | $<0.05$ |
|  | Male | $\operatorname{Ln}(\mathrm{N})=5.16-0.64 \mathrm{t}^{\text {x\& }}$ | 0.64 | 0.527 | 3 | 0.95 | $<0.05$ |
|  | Total | $\mathrm{Ln}(\mathrm{N})=5.69-0.56 \mathrm{t}^{\circ}$ | 0.56 | 0.571 | 5 | 0.92 | $<0.05$ |
| Astrovitsa | Female | $\operatorname{Ln}(\mathrm{N})=7.99-1.65 \mathrm{t}$ * | 1.65 | 0.192 | 3 | 0.92 | <0.05 |
|  | Male | $\operatorname{Ln}(\mathrm{N})=6.70-1.92 \mathrm{t}^{+8}$ | 1.92 | 0.146 | 4 | 0.95 | <0.05 |
|  | Total | $\mathrm{Ln}(\mathrm{N})=8.54-1.80 \mathrm{t}^{\circ}$ | 1.80 | 0.165 | 4 | 0.94 | <0.05 |
| Alykes | Female | $\operatorname{Ln}(\mathrm{N})=5.17-0.93 \mathrm{t}^{* *}$ | 0.93 | 0.394 | 4 | 0.99 | <0.05 |
|  | Male | $\operatorname{Ln}(\mathrm{N})=5.87-1.61 \mathrm{t}^{*}$ | 1.61 | 0.199 | 4 | 0.99 | $<0.05$ |
|  | Total | $\operatorname{Ln}(\mathrm{N})=6.10-1.18 \mathrm{t}^{\circ}$ | 1.17 | 0.310 | 4 | 0.99 | $<0.05$ |

Comparison of slopes (Z) between males and females at each sampling station: ${ }^{\times} \mathrm{F}=0.064$, $\mathrm{p}=0.810 ;{ }^{+} \mathrm{F}=5.446, \mathrm{p}=0.058 ; * \mathrm{~F}=0.041, \mathrm{p}=0.849$. The slopes do not differ significantly between them at probability level 0.05 .
Comparison of slopes ( Z ) of the same sex between the sampling stations: ${ }^{*} \mathrm{~F}=79.138, \mathrm{p}<0.001$; ${ }^{\&} \mathrm{~F}=6.813, \mathrm{p}=0.037$.
All the slopes differ significantly between them at probability level 0.05 .
Comparison of slopes ( $Z$ ) between the three sampling stations: ${ }^{\circ} \mathrm{F}=2.26, \mathrm{p}=0.15$. The slopes do not differ significantly between the sampling stations at probability level 0.05 .
body length-scale radius, $\mathrm{L}_{\infty}$, T -temperature ( ${ }^{\circ} \mathrm{C}$ ), salinity (ppt), and these correspond to characteristics of individuals at station $\mathrm{AL}\left(\mathrm{L}_{\infty}\right.$ characterizing mainly the males at station AL). Mortality characterizes the individuals at station AS.

## DISCUSSION

A. fasciatus exhibits sexual dimorphism, particularly during the reproductive period, when males have a very strong coloration (Kiener and Shachter, 1974). Dimorphism is manifested as a series of differences between the sexes such as length and shape of fins. Boumaiza (1980) in a study of fish in Tunisia reported that the length of the caudal fin of males is always larger than that of the females. Nikolsky (1963) associated the changes in size of the fins with the variability of reproduction and reported that in the males of some carp, the paired and unpaired fins, are slightly larger than those of the females. It appears in this study that one of the manifestations of sexual dimorphism is the observation of differences in length of the caudal fin between the sexes. The differences in length of the caudal fin between the stations observed in this study is probably due to the polymorphism shown by the species as a result of differring environmental conditions.

The values of $b$ in the equation relating length and somatic weight range from 3.10 to 3.44 and in most cases differ significantly from 3, and therefore show an allometric


Fig. 5. Principal Components Analysis (PCA) between biological-physiochemical parameters (A) and the sampling stations (B). The letters $m$ and $f$ after each code of the sampling stations denotes males and females, respectively.
increase (Ricker, 1975) (Table 3). Bagenal and 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. It would appear that the males are affected more than the females by extreme environmental conditions; for example, at AL females are heavier than males of the same length. The values of $b$ differ greatly from the values determined by Penaz and Zaki (1985) for Lake Mariut, Egypt, where the following relationships where found : $\mathrm{W}=0.0068 \mathrm{TL}^{3.619}$ for females, and $\mathrm{W}=0.0156 \mathrm{TL}^{2.740}$ for the males.

By comparing the data of size composition (Fig. 3) with the results of scale readings (Table 5-7) we found that in most cases the method of length-frequency gave correct results.

The formation of the annual ring appears to occur after the period in which the lowest water temperature is observed (Fig. 2). Weatherley (1987) reports that some of the factors that can induce the formation of the annual rings are: low or high temperature, reduced food intake, and reproductive activity. Fagade (1973), studying the formation of the rings in Tilapia melanotherm in the Lagos Lagoon in the Gulf of Guinea, found that the rings were probably formed during rainfall. At this time salinity is reduced, there is an increase in turbidity and a decrease in temperature, which lead to a reduction in productivity. In the present study, however, primarily temperature (Fig. 2) and food intake are associated with the formation of the annual ring. It should be mentioned that it was not possible to interpret the annual rings of all restored scales and these were not used in the age determination.

The reading of scales of A. fasciatus demonstrated that at station RE there were six age groups for both males and females, at station AS six age groups for females and three for males, and at station AL four age groups for both males and females. The differences in age composition at the three stations are due to the particular environmental conditions that exist at each sampling station. The strong phyletic coloration, large and impressive fins of the males, particularly during the reproductive period, make the males more vulnerable to predators compared to the females, and this is probably the reason for the difference in mortality between males and females (Stergiou et al., 1992). Penaz and Zaki (1985) report that the characteristic dominance of females in populations of $A$. fasciatus could be due either to interruption of male growth during sexual maturity, to higher male mortality rates, or to a shorter life span.

At station RE the fish were protected in the shallow offshore waters, with a depth less than 0.5 m and a silty bottom, but mainly by dense vegetation which in many cases reached up to the surface of the water. These areas are relatively inaccessible to predators.

At station AS the fish are vulnerable to predation by other fish due to the relatively great depth of the water and the absence of sheltered areas. Ktari et al. (1978) report that the majority of the stomach contents of D. labrax consisted of A. fasciatus.

At station AL, there is no predation by fish. The main factors controlling the age composition are the extreme physicochemical conditions of the water, arising from the operation of the saltworks, and the significant presence of water birds (Sterna albifrons). Populations of these were found feeding in areas where there were schools of A. fasciatus. It appears that fish predators at station AS, and the environmental conditions together with bird predators at station AL, are the factors which influence the different population composition of A. fasciatus at the sampling stations. This is indicated by the instantaneous mortality rate which is different between the sexes and between the sampling stations (Table 9).

Length increase is greatest during the first year and independent of sampling station and sex (Murawski, 1978). The highest percentage yearly growth was found at station AL, where fish reached $57.14 \%$ (Table 7) of the maximum length at the end of the first year. At station RE and station AS the highest percentages were $49.05 \%$ (Table 5) and $43.77 \%$ (Table 6), respectively. The yearly growth rate is greatly reduced after completion of the first year.
A. 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 cause of mortality. Beverton and Holt (1956) report that in such cases, calculation of the total instantaneous mortality coefficient ( $Z$ ), gives directly the coefficient for natural mortality (M) of the population.

Mortality, size, and the coefficient of Von Bertalanffy's growth rate are indications of the living regime of fish and are expected to correlate between them (Gulland, 1983). In all cases, the length at infinity $L_{\infty}$ and values of $t_{0}$ were greater for females than males at the same station, while values of k for females were always smaller than those of the males (Table 8). Comparing individuals of the same sex from different sampling stations, it was found that values of Low were lowest at station RE, followed by stations AS and AL and that values of k showed the opposite trend, that is, higher at station RE and lower at stations AL and AS.

Values of asymptotic length, $\mathrm{L}_{\infty}$ showed a slight positive correlation with temperature $(r=0.383)$ and a strong, negative correlation with $k(r=-0.926)$ and with $\mathrm{t}_{\mathrm{o}}(\mathrm{r}=$ -0.827 ) (see also, Fig. 5). Pauly (1980) reported that values of $L_{\infty}$ decreased with increasing values of $k$. High values of growth rate ( $k$ ) and low values of $L_{\infty}$ are expected for fish which have a short lifespan. Generally, k tends to increase with all factors that cause stress or an increased consumption of oxygen.

In this study, it was found that the growth rate (k) had a negative correlation with temperature and salinity (Fig. 5). It appears that the extreme environmental conditions which occur in some seasons (Fig. 2) reduce fish growth.

Studies on the interaction of temperature, salinity, and the rate of growth of the euryhaline species Trinectes maculatus showed that although at $15^{\circ} \mathrm{C}$ the growth rate ( k ) increases as salinity rises from $0-30 \mathrm{ppm}$, at $35^{\circ} \mathrm{C}$ the growth rate decreases with increasing salinity (Wooton, 1990). Comparing values of $k$ with the lifespan of $A$. fasciatus it appears that the high mortality rate $(\mathrm{Z})$ at stations AS and AL are not correlated with intrinsic biological parameters, but with parameters such as the presence of predators and extreme environmental conditions which reduce the lifespan of the fish.

Pauly (1980), who studied the values of natural mortality (M) in 175 populations of fish, found that for populations of A. fasciatus in Southern France values of $L_{\infty}$ were 73 and 63 mm , for k 0.48 and 1.12, and for M 1.8 and 2.6 for female and male fish, respectively. By comparison in this study, calculated values of $L_{\infty}$ were higher, values of k were in all cases lower, and values of M , which correspond to values of Z , were always lower.

Boehlert and Kapperman (1980) reported that the asymptotic length, lifespan, age composition, fecundity, and growth rate can vary with environmental parameters, either through species-specific biological mechanisms, or through evolutionary adaptation due to long-term environmental effects at the population level. Most of these kinds of contrast become pronounced in organisms which live in changing environments, such as lagoons. It appears that the populations of $A$. fasciatus in the sampling areas differ in terms of age composition, sex composition, growth rate ( k ), and the total mortality coefficient ( $Z$ ). The observed differences in biological and population parameters show
that at station AS, and to a greater extent at station AL, than individuals of A. fasciatus are at the r-extreme of the r-K continuum of life-history strategies. At stations AL and AS shorter lifespans, fewer age groups, lower growth rate, and higher mortality are observed than at station RE. At station RE it was found that the A. fasciatus population had higher growth rates and larger average lengths in every age group, a wider range of ages and lower values of total mortality, which together indicate that the A. fasciatus population is at the K extreme of the $\mathrm{r}-\mathrm{K}$ concept.

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