Age, Growth, Sex-ratio, Spawning Season and Mortality of Annular Bream, *Diplodus annularis* Linnaeus (1758) (Pisces:Sparidae) in Edremit Gulf (Aegean Sea)

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**Abstract:** The study was conducted with specimens (N = 532) collected from Northern Aegean coasts of Turkey. Females made up 48.39% and males 51.62% of the species. The fork length of females varied between 7.3 and 19.8 cm, and of males, varied between 7.6 and 14.0 cm. The von Bertalanffy growth equation was fitted on the basis of mean length-at-age data resulting in parameter values of parameters of: \( L_0 = 16.38 \text{ cm}, K = 0.141 \text{ yr}^{-1}, t_0 = 1.75 \text{ for females; } L_0 = 15.82 \text{ cm}, K = 0.201 \text{ yr}^{-1}, t_0 = 1.905 \text{ for combined sexes. } D. \text{ annularis was grown allometrically for both sexes together with } b = 2.75 \text{ (SE= 3.1834) and relatively rapidly, achieved } 28.77 \% \text{ of the weight during the first year. The combor was a relatively long-lived species. The oldest male and female were estimated to be 7 and 8 years old, respectively. The overall sex ratio of males females was 1:1. The total (T) and natural (N) mortality rates were 1.15 and 0.37 per year, respectively. The exploitation rate indicates that the population is overexploited (E = 0.89). Mean condition factor of annular bream was calculated as 1.251. The seasonal values of gonadosomatic index (GSI) of females indicated that spawning occurred mainly in spring and summer.**

**Key words:** *Diplodus annularis*, Edremit Gulf, age, growth, gonadosomatic index, mortality.

**Introduction**

The annular bream (*Diplodus annularis* L) is a demersal species which lives in north Atlantic and Mediterranean sea. The habitat of *D. annularis* restricted to Posidonia beds (Akçakaya, 1987; Bauchot and Hureau, 1988; Fischler et al., 1985-87). In the previous studies, this species is widespread in Mediterranean sea and Aegean sea (Bauchot and Hureau, 1988; Mater, 1987), in the Marmara sea (Unsal, 1984). Sexual maturation, reproduction and fecundity of *D. annularis* from Turkey were investigated (Sezal and Karatay, 1996). Age and growth patterns of *D. annularis*, *D. sargus*, *D. vulgaris* in adult populations were investigated in the northwestern Mediterranean sea (Gordoia and Moli, 1987). Weight-length relationship for *D. annularis* was investigated in the southwestern coast of Portugal (Erzini, 1992). Maturation and growth selectivity of two small sea breams (genus *Diplodus*) from the coast of south Portugal were studied (Sanços et al., 1998). Biologic-ecological aspects of sea breams genus *Diplodus* from the gulf of the Lion were studied (Girardin, 1978). The existence of this species was pointed out in Turkish seas (Erzini, 1942). Biologic-ecology of *D. annularis* was studied briefly from Black sea (Stastanenko, 1965), Age, growth, maturation, and local migration of *D. annularis* were studied from Izmir Gulf (Mater, 1987). The biology of *D. annularis* was studied from the sea of Marmara (Unsal, 1984). The biology and ecology of the species were also reported by Anonymous (1993). Although different aspects of its biology have been studied, such as settlement (Garcia-Rubies and Macpherson, 1986; Hasmiket-Vivian et al., 1996), age and growth of *D. annularis* from Catalan coast (Gordoia and Moli, 1987), any current information is not available on mortality.

The objective of present study is to point out the data on the age and size distribution, length-weight relationship, sex composition, gonadosomatic index, condition factor, and mortality of annular bream (*D. annularis* L) from Edremit Gulf (Aegean Sea).

**Materials and Methods**

**Collection:** A total of 532 specimens of annular bream, *D. annularis* was collected with trawl hauls at monthly intervals, between September 1997 and September 1998. Location was between Altnolu and Bobzurun (Fig. 1). The trawling was done only in the daytime at depths ranging from 45 to 80 m. Duration of hauls was 2 hours and the speed was 2 miles per hour. The trawl was equipped with a 22 mm mesh size net (knot to knot) at the bottom.

For each individual, the following variables were recorded: body length (\( L \), to the nearest 0.5 cm), total weight (TW), gonad weight (GW) and somatic weight (SW), These were recorded with a 0.01 g accuracy. Sex and maturity stages were also determined. The five-point maturity scale used was a simplified version of Pinto and Andreu (1957) maturity scale (stage I = virgin or resting, stage II = maturing, stage III = pre-maturing, stage IV = spawning, and stage V = post-spawning).

**Fig. 1:** The sampling area in Edremit Gulf, Aegean sea

**Growth:** Sagittal otoliths were removed. They were stored dry in paper envelopes and later used for age determination by the method of Chugunova (1893). Age was read from whole otoliths immersed in glycerine (25 %) and alcohol (75 %) and viewed with a low-power binocular microscope under reflected light against a black background.

The length and weight relationship was determined according to the equation given below (Sparrer and Vranems, 1898-1921).

\[ W = a L^b \]

where \( W \) is the total body weight (g), \( L \) the fork length (cm), and \( a \) and \( b \) are constants.
Growth was expressed by the equation of von Bertalanffy (1957):

\[ L_t = L_{\infty} \left[ 1 - e^{-K(t-t_0)} \right] \]

where \( L_t \) is the fork length at age \( t \), \( L_{\infty} \) the asymptotic fork length, \( K \) the growth curvature parameter and \( t_0 \) is the theoretical age when fish would have been at zero fork length. These parameters were estimated according to von Bertalanffy growth equation (Sparre and Venema, 1989-1992).

Sex ratio and reproduction: Seasonal sex ratio, expressed as female: male, was analyzed. Deviations from 1:1 null hypothesis were statistically tested by \( \chi^2 \)-test. Spawning period was determined from the analysis of the seasonal evolution of the percentages of mature individuals and the mean gonadosomatic index (GSI) throughout the one-year period. In these analyses, only those specimens with a size larger than the length at first maturity were considered. Thus avoiding possible size-dependent biases because of the uneven length distribution in seasonal samples. Individual GSI was calculated from the expression:

\[ I_c = \left( \frac{GW}{SW} \right) \times 100 \]

Length at first maturity (Lm) was estimated in both sexes and for the species from the percentages of mature individuals (stage III, IV and VI) occurring over the reproductive period (previously determined from seasonal mean Lm). The total length at which 60% of the individuals were fully mature was estimated from fitting the log-transformed relative frequencies of mature individuals by length class by the least squares method to a logistic curve (Sparre et al., 1989).

Condition factor: Annular bream condition status has been determined seasonally from the condition factor (CF) using the following two expressions: the Fulton's (1911 in Millan, 1999) condition factor \( CF = \frac{SW}{TL^3} \times TL \) measured in cm. The somatic weight (SW) \( SW = TW \times (\text{length weight}-GW \text{ (somatic weight)}) \) was used in order to avoid the influence of gonadal development on the true somatic conditions of individuals (Millan, 1999).

Mortality: Total mortality rate was estimated for both sexes using the cumulated catch curves (Jones and Van Zalinge, 1981)

\[ \log N_t = \alpha + Zk \log L - L_I \]

where \( N_t \) is the cumulative number of the fish of length \( L \) and above, \( L_I \), and \( k \), are the parameters of the von Bertalanffy equation, \( 2k \) the slope of the curve. For the estimation of the total mortality (Z) catch curves were developed from the length distribution. Natural mortality (M) was estimated using the empirical formula of Pauly (1980, 1983):

\[ \log (M) = -0.0066 - 0.2791 \log (L) + 0.65431 \log (k) + 0.48341 \log (T) \]

where \( L_0 \) and \( k \) are the parameters derived from von Bertalanffy equation and \( T \) the mean annual environmental temperature at the surface of the study area in degrees centigrade (16°C for 0-30 m depth). Following estimation of Z and M, the fishing mortality rate (F) was estimated from:

\[ F = Z - M \]

and the exploitation ratio \( E \) from:

\[ E = F / Z \]

Results and Discussion

The length-frequency distribution: Of the 652 specimens measured, the fork length of females (49.38%) ranged from 7.3 to 13.6 cm. The range (7.5-14.0 cm) for males (50.62%) was higher than females (Fig. 2). The immature individuals were regarded as males because of rudimentary ambi-sexuality in the species (Unsal, 1984; Said and Kartas, 1985). However, the difference between overall mean fork length of female and male fish was non significant.

The fork length-weight relationship: The fork length-weight relationships were evaluated separately for males, females (Fig. 3). The calculated weight-length equation for females was:

\[ W = 0.0387L^{2.777} \quad (r = 0.93) \]

for males \( W = 0.0455L^{2.604} \quad (r = 0.92) \). Weight increased negatively allometrically with size since the value of \( b = 2.7976, b = 2.6984 \), respectively had a significant difference from the value 3.0 \( P < 0.05 \).

Age and growth: The results of otolith rings are given in Table 1 and Table 2. The maximum age determined was 7. The age 3 (49.38%) were dominant for females and 2 (44.89%) for males. In females, the age 2 (36.96%), 4 (33.52%), and 5 (31.24%), followed Table 1: The calculated and observed fork length at different age groups

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1</td>
<td>7.30 ± 0.3872</td>
</tr>
<tr>
<td>2</td>
<td>9.36 ± 0.2713</td>
</tr>
<tr>
<td>3</td>
<td>10.62 ± 0.5624</td>
</tr>
<tr>
<td>4</td>
<td>11.81 ± 0.4439</td>
</tr>
<tr>
<td>5</td>
<td>12.35 ± 1.2727</td>
</tr>
<tr>
<td>6</td>
<td>13.80 ± 0.0001</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
</tr>
</tbody>
</table>
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Fig. 3: Length–weight relationships. (A) females and (B) males

![Graph showing length-weight relationship for females and males.](image)

Fig. 4: Maturity ogive and length at first maturity ($L_M$) in (A) females and (B) males of $D$. annulatus for the whole study period.

![Graph showing maturity ogive and length at first maturity for females and males.](image)

Fig. 5: Seasonal cycle of gonadosomatic index of $D$. annulatus.

In males, age 3 (42.42%) was followed by 4 (10.30%), and 1 (1.82%), respectively. The greater portions of the population are composed by the ages, 3 and 2.

The estimated parameters values of the von Bertalanffy growth equation were:

- $L_\infty = 18.36$ cm, $K = 0.141$ /year, $t_0 = -2.93$ (median), $r^2 = 0.923$ for males,
- $L_\infty = 17.21$ cm, $K = 0.211$ /year, $t_0 = -1.73$ (median), $r^2 = 0.932$ for females,
- $L_\infty = 18.52$ cm, $K = 0.201$ /year, $t_0 = -1.88$ (median), $r^2 = 0.928$ for both sexes combined.

The value of $L_\infty$ is higher than the maximum observed length. A theoretically maximum length of 16.52 cm is realistic because the largest specimen sampled during the survey was 14.0 cm.

Fig. 6: Seasonal cycle of the Fulton's condition factor of $D$. annulatus.

Sex ratio and reproduction: It was found that of the 652 specimens measured, 322 were females (49.53%) and 330 (50.42%) were males, but the gonads of 281 males included in various age groups had only testicular tissue, while the gonads of 39 males (5.99%) in all specimens belonging to IV and VII age groups had partly developed ovaries together with testes. On the basis of Reiberth's (1870) study, these individuals were considered as males.

The overall female: male ratio (0.97) was similar with expected 1:1 ratio ($X^2=18.82$, $p>0.001$). The female: male ratio and corresponding chi-square ($X^2$) values for per season are presented in Table 3.
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Table 2: Age-length key for annular bream in Edremit Bay based on scale reading

<table>
<thead>
<tr>
<th>Length group (cm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>3.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>13.00</td>
<td>35.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>130.00</td>
<td>100.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>225.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>73.00</td>
<td>30.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.00</td>
<td>33.00</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3.00</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1.0</td>
<td>2.00</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (N)</td>
<td>16.0</td>
<td>165.00</td>
<td>389.00</td>
<td>86.00</td>
<td>3.0</td>
<td>2.00</td>
</tr>
<tr>
<td>%</td>
<td>2.5</td>
<td>25.00</td>
<td>61.00</td>
<td>10.00</td>
<td>0.5</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean L (cm) ± SD</td>
<td>7.08</td>
<td>9.11</td>
<td>10.33</td>
<td>12.1</td>
<td>13.27</td>
<td>14.2</td>
</tr>
<tr>
<td>Mean W (g) ± SD</td>
<td>0.36</td>
<td>0.25</td>
<td>0.705</td>
<td>0.434</td>
<td>1.01</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 3: Numbers of female and male annular bream per season and results of the chi-square (X²) test

<table>
<thead>
<tr>
<th>Seasons/Year</th>
<th>No. of females</th>
<th>No. of males</th>
<th>Female:Male ratio</th>
<th>Different from 1:1 (P)</th>
<th>Chi-square (X²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn/97</td>
<td>93.0</td>
<td>75.0</td>
<td>1.3</td>
<td>&lt;0.001</td>
<td>2.91</td>
</tr>
<tr>
<td>Winter/97</td>
<td>73.0</td>
<td>73.0</td>
<td>1.0</td>
<td>&lt;0.001</td>
<td>0.1</td>
</tr>
<tr>
<td>Spring/98</td>
<td>73.0</td>
<td>73.0</td>
<td>0.3</td>
<td>&lt;0.001</td>
<td>5.77</td>
</tr>
<tr>
<td>Summer/98</td>
<td>133.0</td>
<td>128.0</td>
<td>1.0</td>
<td>&lt;0.001</td>
<td>0.24</td>
</tr>
<tr>
<td>Autumn/98</td>
<td>15.0</td>
<td>37.0</td>
<td>0.4</td>
<td>&lt;0.001</td>
<td>9.30</td>
</tr>
</tbody>
</table>

Table 4: Age structure, parameters of the length-weight relationship (a, b) and the growth (L₅₀, k, t₀) of the D. annularis

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study area</th>
<th>Max. age (years)</th>
<th>N</th>
<th>a</th>
<th>B</th>
<th>rₚ</th>
<th>L₅₀</th>
<th>k</th>
<th>T₀</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matar (1976)</td>
<td>Gulf of Izmir</td>
<td>9</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9-11</td>
</tr>
<tr>
<td>Girardin (1978), L</td>
<td>Gulf of Lion</td>
<td>5</td>
<td>5</td>
<td>3.34</td>
<td>-</td>
<td>-</td>
<td>17.12</td>
<td>0.56</td>
<td>-0.0226</td>
<td></td>
</tr>
<tr>
<td>Unsal (1984)</td>
<td>Marmara Sea</td>
<td>8</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.84</td>
<td>19.65</td>
<td>-</td>
<td>5-18</td>
</tr>
<tr>
<td>Gordoa and Moli (1997), L</td>
<td>Catalan (Spain)</td>
<td>6-7</td>
<td>6-7</td>
<td>0.0252</td>
<td>2.79</td>
<td>0.81</td>
<td>20.37</td>
<td>0.544</td>
<td>-0.033</td>
<td>9-20</td>
</tr>
<tr>
<td>Saied and Kartas (1995)</td>
<td>Sud est Tunisia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5-19</td>
</tr>
<tr>
<td>This study (2000)</td>
<td>Gulf of Edremit</td>
<td>7</td>
<td>652</td>
<td>3.075</td>
<td>2.75</td>
<td>0.85</td>
<td>16.620</td>
<td>0.20</td>
<td>-1.96</td>
<td>7.3-14</td>
</tr>
</tbody>
</table>

**Length at first maturity:** For the whole period, length at first maturity (L₅₀) was estimated as 11.20 ± 3.534 cm for females and 11.13 ± 3.534 cm for males (Fig. 4). Examination of the sampled female ovaries showed that the sexual maturity was reached after age group II. The L₅₀ results revealed that the reproduction occurred from spring to the end of the season when the L₅₀ reached its highest level (Fig. 6).

**Condition factor:** From 1997 to 1998, seasonal trends in CF showed a rather apparent seasonal cycle (Fig. 8), annular bream reaching a higher condition from autumn to winter and a lower condition from spring to summer. This cycle of CF showed a negative correlation with that of L₅₀ (r = -0.887; n = 262; p < 0.01) (Fig. 6).

**Mortality:** The fishing net used was capable of catching D. annularis with a fork length 7.3 cm or greater. Total mortality was estimated from both sexes combined. The total mortality corresponding with slope of the curve was found to be 2 = 1.16/year. The natural mortality (M) was found to be M = 0.37/year. Then the calculation of the fishing mortality gave F = 0.88/year. The exploitation rate was computed as E = 0.68. indicating that the fishing pressure exerted on the D. annularis in Edremit Gulf, is rather high.

The sagittal otoliths of D. annularis show distinct opaque and hyaline bands which can be used for age determination. Few otoliths were rejected.

D. annularis has relatively long lifespan. There are seven age classes of D. annularis in Edremit Gulf, compared with eight age classes in Marmara Sea (Unsal, 1984). The seven age classes life cycle exhibited by D. annularis in Edremit Gulf concurs with the expectations of Gordoa and Moli (1997), who proposed six and seven classes structure, while there is a five age classes structure in Lion Gulf (Girardin, 1978). Matar (1976) found that there are nine age classes in some populations of D. annularis in Izmir Gulf (Table 3). The rapid early growth rate after age one decreased to age seven gradually. The estimated L₅₀ (16.82 cm) derived from the von Bertalanffy equation was not in agreement with the results of previous investigators, except for the result of Girardin (1978). The overall growth rate indicated by the von Bertalanffy growth coefficient (k = 0.20/year) calculated in the present study has been the lowest found in the literature so far. A trade-off between growth rate k and maximum size L₅₀ is found because of several factors such as temperature, mortality or food availability and this may also be due to the ageing procedure (otoliths) (Table 4).

There is no protandry but a rudimentary ambisexuality in D. annularis (Unsal, 1984). Saied and Kartas (1995) also mentioned that D. annularis in the Mediterranean Basin, Marmara Sea, and Karkennah Islands (Sud-Est Tunisien) also falls in spring and summer but there are differences as to years, regions and the investigators in the same region.

The proportion of males and females of D. annularis in the population appears to depend on temporal factors such as the reproduction period. The almost equal numbers of the both sexes
are born and enter into the population, while an unequal sex ratio during the reproduction period indicates that during the spawning season more males appeared than females (Table 3). The lack of 0+ age group observed is due to the selectivity of the cod-end used in trawl nets. The low percentage of age groups VI-VII and the presence of individuals up to 14 cm can be contributed to the outcome of extremely intensive fishing efforts, which is not under control. *D. annularis* has commercial value due to its abundance and its relative easiness of catch.

The length-converted catch curves showed a typical form and justified the estimation of a single value of Z in all fish (Pauly, 1980, 1983). In every case, the exploitation ratio (E) is higher than 0.50. As a rule, a fish stock is optimally exploited at level of fishing mortality which generates E=0.50, where F*Z*=M, but in present study F>1=Z (Gulland, 1971 in Pajuelo and Lorenzo, 1998).

Therefore, the stock of annular bream is being heavily exploited. The fisheries strategy should be planned so that the fishing period follows the reproductive period.

**References**


