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Growth and reproduction of large-scaled gurnard (*Lepidotrigla cavillone* Lacepède, 1801) (Triglidae) in the central Aegean Sea, eastern Mediterranean

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Abstract: Age, growth, and reproduction of the large-scaled gurnard were studied in the central Aegean Sea to provide fisheries managers with the essential data for science-based management. A total of 2342 samples were collected by trawl hauls between July 2004 and June 2007 from İzmir Bay (Turkey). The size of the samples ranged from 3.4 to 15.2 cm total length and the samples were composed of 35.2% females, 25.7% males and 39.1% immature individuals, with a female to male ratio of 1:0.73. The length-weight relationship was calculated as $W = 0.0086L^{3.16}$ for all samples. The age composition of the samples was from I to VI and the estimated von Bertalanffy growth parameters were $L_\infty = 15.96$ cm, $W_\infty = 54.35$ g, $t_o = -0.018$ year, and $k = 0.483$ year^{-1}, with a growth performance index of 2.09 (φ'). Reproduction started in February and continued to June. The total fecundity ranged from 503 to 10,046 oocytes/female and showed a significant correlation with fish length and weight. The size at first maturity was estimated at 10.55 cm total length and the maturity age was found to be 2-year-old in both sexes.

Key words: Large-scaled gurnard, *Lepidotrigla cavillone*, age, growth, reproduction, Aegean Sea

Orta Ege Denizi (Doğu Akdeniz) kırlangıç balığı'nın (*Lepidotrigla cavillone* Lacepède, 1801) (Triglidae) büyüme ve üreme özellikleri

Özet: Bilimsel temele dayalı bir balıkçılık yönetiminin ihtiyaç duyduğu bilgileri sağlamak için, Orta Ege Denizi kırlangıç balığı'nın yaş, büyüme ve üreme özellikleri çalışılmıştır. Çalışmada, Temmuz 2004 ile Haziran 2007 tarihleri arasında dip trolü ile toplam 2342 adet birey örneklenmiştir. Bireylerin, 3,4 cm ile 15,2 cm total boyları arasında dağılım gösterdiği tespit edilmiştir. Örneklerin % 35,2'sinin dişi, % 25,7'sinin erkek ve % 39,1'inin ise eşeysel olgunluğa erişmemiş bireylerden oluştuğu ve stoğa ait eşey oranının 1:0,73 olduğu tespit edilmiştir. Tüm bireyler için boy-ağırlık ilişkisinin $W = 0,0086L^{3,16}$ olduğu hesaplanmıştır. Örneklerin, I ile VI yaşları arasında dağılım gösterdiği, von Bertalanffy büyüme parametrelerinin $L_\infty = 15,96$ cm, $W_\infty = 54,35$ gr, $t_o = -0,018$ yıl ve $k = 0,483$ yıl^{-1} olduğu tahmin edilmiş ve büyüme performans indeksi 2,09 (φ') olarak hesaplanmıştır. Üremenin Şubat'ta başladığı ve Haziran'a kadar devam ettiği belirlenmiştir. Yumurta verimliliğinin 503 ile 10.046 yumurta/dişi arasında olduğu ve bu verimin balık boyu ve ağırlığı ile ilişkili olduğu tespit edilmiştir. Her iki eşey için ilk üreme boyu ve yaşı 10,55 cm total boy ve 2 yaş olarak hesaplanmıştır.

Anahtar sözcükler: Kırlangıç, *Lepidotrigla cavillone*, yaş, büyüme, üreme, Ege Denizi

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Introduction

The large-scaled gurnard, *Lepidotrigla cavillone* (Lacepède, 1801), is a small demersal species of the family of Triglidae and the length of the species can reach to 20 cm (Hureau, 1986). The large-scaled gurnard is the most common gurnard species in the Mediterranean (Colloca et al., 1997). Although there are 114 gurnard species existing in the world, only 8 gurnard species are found in the Mediterranean and Turkish waters (*Aspitrigla cuculus*, *Chelidonichthys lucerna*, *C. obscurus*, *Eutrigla gurnardus*, *Lepidotrigla cavillone*, *L. dieuzeidei*, *Trigla lyra,* and *Trigloporus lastoviza*) (Froese and Pauly, 2009). The species prefers muddy sand and gravel bottom substrates and lives at depths between 30 and 450 m (Hureau, 1986) but the maximum abundance is at 60-200 m depth for the Aegean Sea (Papacostantinou, 1983). Geographic range for this species was described as eastern Atlantic (southern coast of Portugal to Mauritania) and Mediterranean, but is not found in the Black Sea (Froese and Pauly, 2009). The species feed on mysids, decapods, and small crustaceans (Labropoulou and Machias, 1998). According to Colloca et al. (1997), the large-scaled gurnard is an important commercial species for the Mediterranean, but it has a very low commercial value in Turkey. It was defined as a discard species for beach-seining by Akyol (2003); for trawl fishing by Lamprakis et al. (2003); for trawl and purse-seine by Olim and Borges (2006); and also by-catch species of the inshore trawl fisheries by Tsimenides et al. (1992).

There are a few studies on the reproduction and growth of the large-scaled gurnard. Biological characteristics of the species have been studied by Colloca et al. (1997) in the central Tyrrhenian Sea (Latium coasts, Italy); by Toğulga et al. (2000) in the central Aegean Sea (Gülbahçe Bay, Turkey), and by Uçkun (2005) in the northern Aegean Sea (Edremit Bay, Turkey). Caragitsou and Papacostantinou (1990) reported some information on feeding habits in Greek waters and Labropoulou and Machias (1998) studied distribution patterns and feeding habits at Crete Island (Mediterranean).

The main objective of this study was to investigate length distribution, sex ratio, length-weight relationship, age, growth, spawning period, fecundity, first maturity age, and length of the large-scaled gurnard for the central Aegean Sea. This study also presents the first data on the reproduction of the large-scaled gurnard in the Aegean Sea.

Materials and methods

The large-scaled gurnard samples for the study were collected from trawl hauls taken at İzmir Bay (Figure 1), by R/V Egesüf (26.8 m length, 463 HP engine, and 110 gross t weight); sampling period was from July 2004 through June 2007. The sampling was carried out in daytime and the samples were collected at monthly intervals. The trawl surveys were

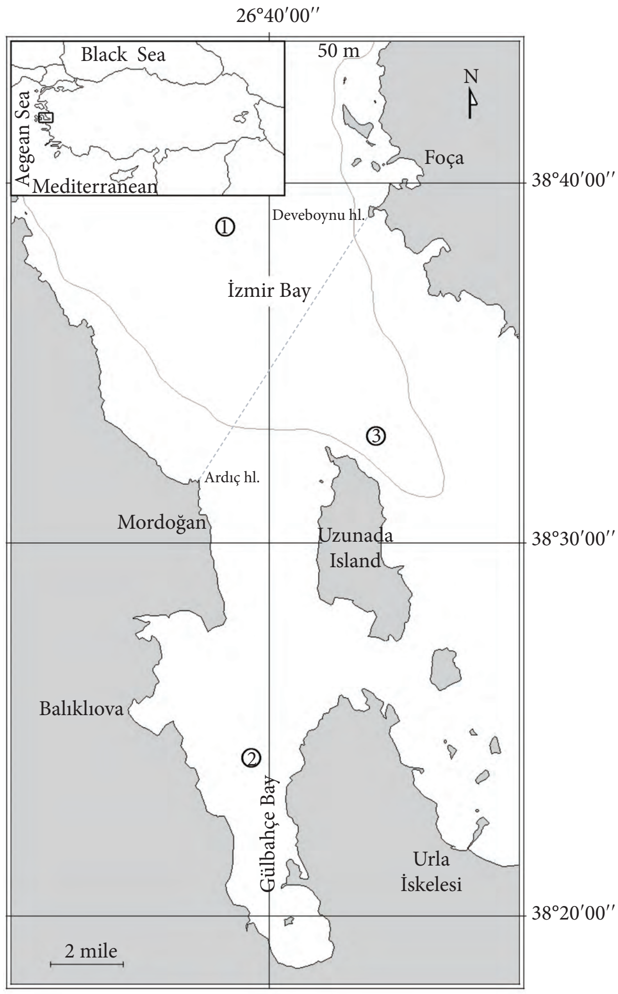

Figure 1. The study area and location of sampling stations where the large-scaled gurnard were collected. (①: Commercial trawl area (The north part of line between Deveboynu and Ardıç Headland); ②: Gülbahçe Bay (Prohibited trawl area); ③: The northwest part of Uzunada Island (no-fishing zone)).

performed using a conventional bottom trawl in 30 to 70 m depth on sandy and muddy bottoms. The towing durations were 1 hour and the average towing speed was 2.3 knots (ranging between 2.2 and 2.4 knots). The cod-end was knotless diamond shaped mesh and made of polyamide (PA) material with 22 mm stretched mesh size.

All captured samples were collected and transported in ice to the laboratory for analysis and total length (*LT*) was measured to the nearest mm. Total weight (*W*) and gonad weight (W_g) were measured to the nearest 0.01 g, and sex was recorded. Fish lengths were classified in 0.5 cm group intervals and length-frequency diagrams were drawn yearly using pooled data.

Sex and maturity were determined by macroscopic inspection of the gonads. The maturity stages were assessed according to Gunderson's (1993) scale: stage I, immature; stage II, resting; stage III, developing; stage IV, ripe; and stage V, spent. The female:male (F:M) ratio was calculated for the samples using the mature individuals after the elimination of immature ones. The chi-square (x^2) test was used to detect differences in the sex ratio and one-way ANOVA was performed to analyze differences in mean length of the sexes.

The relationship between length and weight was established as $W = aL^b$, where *W* is total body weight (g), *L* is total length (cm), and *a* and *b* are coefficients (Ricker, 1973). The parameters *a* and *b* of length-weight relationships were estimated by linear regression analysis on log-transformed data. The association degree between variables was calculated by the determination coefficient (R^2). The growth type was identified by Student's *t*-test.

Sagittal otoliths were used for age determination. A total of 360 individuals were selected randomly to represent all length groups, and the sagittal otolith pairs were removed, cleaned, and stored in dry conditions inside the microplate. Considering their physical and chemical characteristics, some otoliths were prepared for age readings by profiling, rubbing, and polishing. They were imbedded in polyester molds, cut by an Isomet Low Speed Saw, polished with sandpaper (type 400, 800, and 1200), and finally polished with 3, 1, and ¼ μ particulate alumina (Metin and Kınacıgil, 2001). Age determination was performed using a stereoscopic zoom microscope under reflected light against a black background. Opaque and transparent rings were counted: 1 opaque zone, together with 1 transparent zone, was considered the annual growth indicator. Age estimations were made by 2 independent readers.

Growth was analyzed by fitting the von Bertalanffy growth function to size-at-age data using standard nonlinear optimization methods (Sparre and Venema, 1998). The function $L_t = L_\infty[1-e^{-k(t-to)}]$ was applied to the data where L_t is the fish length (cm) at the time *t* (year), L_∞ is the asymptotic length (cm), *k* is the growth coefficient (year^{-1}), and t_o (year) is the hypothetical time at which the length is equal to zero. The accuracy of the growth parameters was tested using Munro's growth performance index ($\varphi' = \log(k) + 2\log(L_\infty)$) and *t*-test (Pauly and Munro, 1984).

Spawning period was established with monthly variations of the gonadosomatic index (*GSI*) from the equation $GSI = [W_g / (W-W_g)] * 100$, where W_g is the gonad weight (g), *W* is the total weight (g) of fish (Ricker, 1975).

A total of 54 female individuals in the advanced maturity stage (IV) were used for fecundity estimation. Fecundity was estimated as batch and total fecundity. Batch fecundity (*BF*) was estimated by the oocyte size frequency method (Hunter et al., 1985). For the batch fecundity estimation, the hydrated oocyte method couldn't be used due to few gonads with hydrated oocytes. According MacGregor (1957), if the number of females with hydrated oocytes is insufficient for a batch fecundity estimate, the oocyte size frequency distribution method can be employed. For counting, approximately 0.5 g of oocytes were taken from the anterior, middle, and posterior parts of the ovary. The entire oocyte content was counted for ovaries weighing less than 1.5 g. Counting and measuring were carried out under stereoscopic zoom microscope. Oocytes greater than 0.73 mm in diameter were considered large. The total number of oocytes in the ovaries was calculated as $F = nG / g$, where *F* is fecundity, *n* is the number of eggs in the subsample, *G* is the total weight of the ovaries, *g* is the weight of the subsample in the same units. The relation between length and fecundity was estimated by fitting power functions ($F = aL^b$), and the between the relationship weight and fecundity was estimated by fitting linear function ($F = aW + b$).

Length at first maturity (L_m) was defined as the length at which 50% of the population investigated was near to spawning (King, 1996). The length at 50% maturity was determined with the L50 computer program by LogLog function (İlkyaz et al., 1998). The equations $r(l) = \exp(-\exp(-(a + bl)))$ and $L_m = (-\ln(-\ln(0.5)) - a) / b$ were applied, where $r(l)$ is the proportion of matures in each length class (%), l is the fish length (cm), L_m is the mean length at sexual maturity (50%, cm), a is intercept, and b is slope.

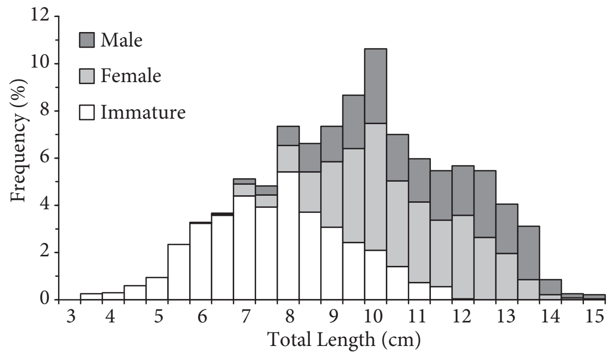

Figure 2. Total length-frequency distribution of the large-scaled gurnard (*Lepidotrigla cavillone*) for immature, females, and males in the central Aegean Sea.

Results

In this study, a total of 2342 individuals were sampled during the study period. It was determined that 824 of the samples were females (35.2%), 603 males (25.7%), and 915 immature (39.1%). The female:male ratio was calculated as 1:0.73 and chi-square analysis showed that it was statistically significant ($x^2 = 34.2$, $P < 0.05$).

The total length-frequency distribution of the large-scaled gurnard is shown in Figure 2. The minimum size observed in May was 3.4 cm total length (0.45 g) while the maximum size found in April was 15.2 cm total length (43.20 g). The average total length and total weight of the individuals were calculated as 9.7 ± 0.05 cm and 13.32 ± 0.18 g ($\bar{x} \pm se$), respectively. The average length of the females was 10.60 ± 0.05 cm; and for males 11.08 ± 0.07 cm. The ANOVA showed that average body length difference between sexes is statistically significant ($F = 29.4$, $P < 0.05$).

Because there was a significant statistical difference for sex ratio and mean length between sexes, the length-weight relationship was calculated separately for females, males, and all samples. The overall length-weight equation was $W = 0.0086L^{3.16}$, for females $W = 0.0081L^{3.19}$, and for males $W = 0.0091L^{3.13}$ (Figure 3). The b-values showed a significant difference in isometric growth for both sexes (for females 95% CI of b (CI_b) = 3.15-3.23; for males CI_b = 3.10-3.17) and all fishes (CI_b = 3.14-3.17, t-test, $P < 0.05$). The b-values and the t-test results show that positive allometric growth was observed for male, female, and all fish.

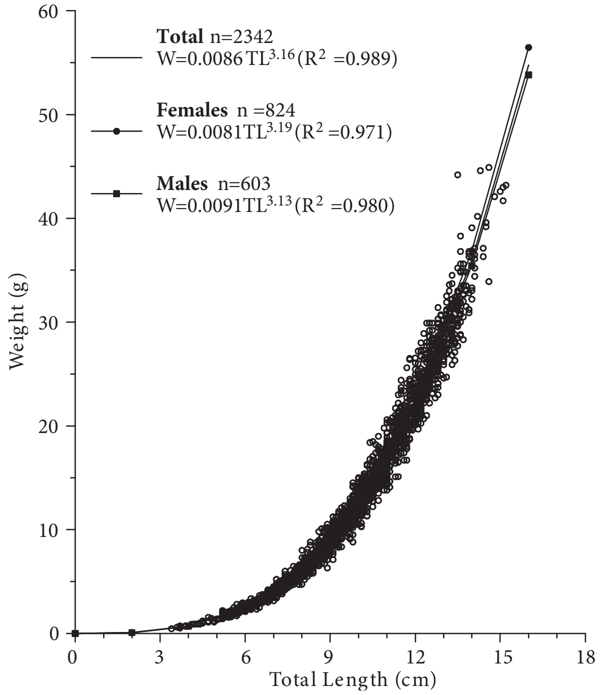

Figure 3. The length-weight relationships of the large-scaled gurnard (*Lepidotrigla cavillone*) for total, females, and males in the central Aegean Sea.

According to the results of otolith readings, the age distribution of individuals varied between I and VI. The age group II (47.6%) was dominant, followed by I (23.9%), III (21.5%), IV (6.3%), V (0.6%), and VI (0.2%) age groups. The large-scaled gurnard achieve a mean length of approximately 6.20 ± 0.18 cm in the first year; 9.98 ± 0.19 cm in the second; 12.29 ± 0.13 cm in the third; 13.47 ± 0.10 cm in the fourth; 14.50 ± 0.21 cm in the fifth, and 15.15 ± 0.05 cm in the sixth year ($\bar{x} \pm se$). The infinite length (L_∞) was 15.96 cm; the infinite weight (W_∞) was 54.35 g; the theoretical age of the fish prior to hatching from the egg (t_o) was –0.018 year; and the growth coefficient (k) was 0.483 year^{-1}. For all samples, the growth curve fitted by length at age data is given in Figure 4. The growth model was $L_t = 15.96[1 - e^{-0.483(t-(-0.018))}]$ ($R^2 = 0.996$), $L_t = 16.88[1 - e^{-0.331(t-(-0.681))}]$ ($R^2 = 0.997$), and $L_t = 14.88[1 - e^{-0.500(t-(-0.756))}]$ ($R^2 = 0.890$) for all samples, female, and male, respectively. In addition, the growth performance index (φ') was calculated as 2.09 for all samples, 1.97 for female, and 2.04 for male.

The average gonadosomatic index values were calculated monthly for female and male samples and the results are given in Figure 5. For females, the gonadosomatic index values ranged between 0.66-6.11 and for males 0.14-0.82. The mean gonadosomatic index value was 3.67 ± 0.12 for female and 0.29 ± 0.03 for male ($\overline{GSI} \pm se$). In both sexes, the maximum gonadosomatic index value was shown in February. While a second gonadosomatic index peak was shown in July and a third in October for females, the peak observed only in February for males. In both sexes, gonads start to mature in January. It was observed that main reproduction started in February and continued until June, when the standard error of *GSI* was also high. It may be suggested that the species reproduction continues throughout the year.

Fecundity was correlated with total length and total weight, and the relationships are given in Figure 6. The samples length range between 7.7 and 14.8 cm (10.83 ± 0.24); and the number of eggs in these specimens ranged from 503 to 10,046 (3252 ± 319).

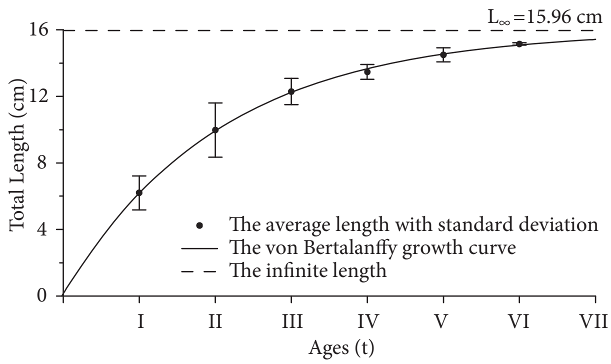

Figure 4. The von Bertalanffy growth curve of the large-scaled gurnard (*Lepidotrigla cavillone*) in the central Aegean Sea.

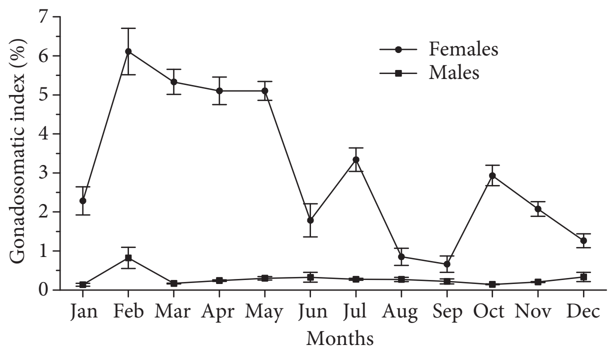

Figure 5. Monthly average gonadosomatic index (*GSI*) values (%) with standard error per month for females and males of the large-scaled gurnard (*Lepidotrigla cavillone*) in the central Aegean Sea.

The egg diameters varied from 0.20 to 1.00 mm, and average egg size was calculated as 0.5323 ± 0.0015 mm. The relationships between fecundity (F) and total length (TL), total weight (W) were calculated as $F = 0.278TL^{3.848}$ ($R^2 = 0.697$) and $F = 221.17W - 605.41$ ($R^2 = 0.763$) respectively. Furthermore, the relationships between batch fecundity (BF) and total length (TL) were calculated as $BF = 0.022TL^{4.041}$ ($R^2 = 0.303$); batch fecundity (BF) and total weight (W) were calculated as $BF = 34.99W - 96.25$ ($R^2 = 0.566$).

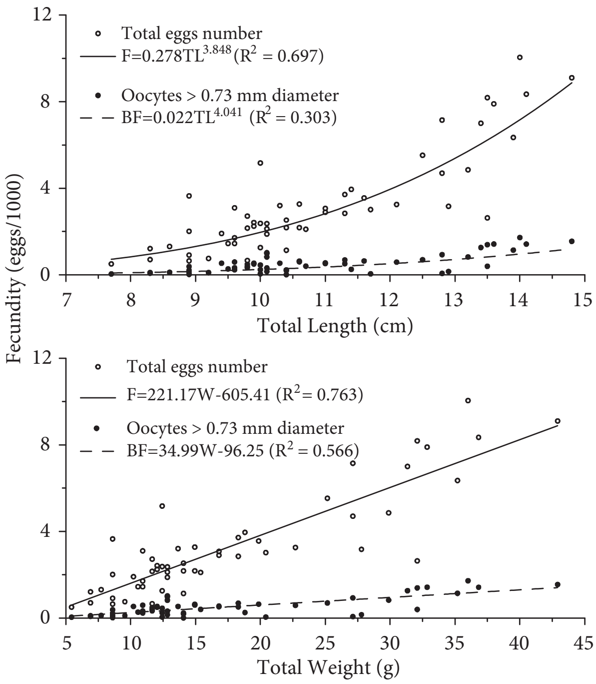

Figure 6. The relationships between total length/weight and batch/total fecundity of the large-scaled gurnard female (*Lepidotrigla cavillone*) in the central Aegean Sea.

The best correlation was found between fecundity and weight of the fish.

It was observed that the smallest female was 6.7 cm (1-year-old) and the smallest male was 6.2 cm total length (1-year-old). Gonad maturity in 50% of the individuals was found at 10.55 cm total length for both sexes (Figure 7). $r_f = \exp(-e^{-(-21.613+2.048l)})$ (R^2 = 0.904), $r_m = \exp(-e^{-(-22.186+2.104l)})$ (R^2 = 0.912). The sexual maturity age was found to be at 2 years for both sexes.

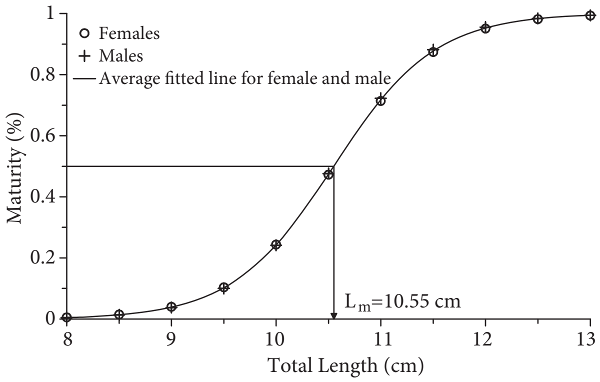

Figure 7. Length at first maturity estimation of the large-scaled gurnard (*Lepidotrigla cavillone*) for females and males in the central Aegean Sea.

Discussion

The sex ratio is an important parameter for fish stocks. This ratio is generally close to 1:1 for the majority of species (Nikolsky, 1963). However our findings for this species showed that there was a statistically significant difference from this equality. The sex ratio was reported as 1:0.12 for Gülbahçe Bay, which is a part of our study area by Toğulga et al. (2000). Although these findings point out a big difference, it is well known that sex ratio varies from year to year in the same population (Nikolsky, 1963). Moreover, this ratio is also reported by Uçkun (2005) to favor females in the north Aegean Sea (1:0.78), and by Colloca et al. (1997) in the central Tyrrhenian Sea (1:0.93). All previous studies reported that the occurrence of females was higher than that of males.

The slope values (b) in the length-weight relationship of the females, males, and all samples were determined to be higher than cubic growth. The standard error of slope (SE_b) and 95% confidence limit of slope (95% CL_b) showed that growth was positive allometric. Olim and Borges (2006) reported similar results on the Algarve coast (Portugal) for the female, male, and all samples; however, isometric growth was reported by Uçkun (2005) in the northern Aegean Sea. The highest and the lowest b-value were reported by Lamprakis et al. (2003) in the northern Aegean Sea (Thracian Sea, Greece) as 3.241 and 2.865. Toğulga et al. (2000) reported higher b-values for total samples (3.073) and for females (3.111), and lower for the males (2.877) but did not give growth type or standard error of b. These findings seem to be relatively similar our findings except for males. These differences may be caused by the lower sample size (n=25, Toğulga et al., 2000). The b-values are often 3 and range between 2.5 and 3.5 and in each fish population may differ according to the species, sex, age, sexual maturity of fish, season and fish feeding (Ricker, 1975). Furthermore, the data sets include early juveniles which for most fish have not yet obtained adult body shape (Safran, 1992), or include very old specimens which often have distorted body forms with unusually high proportions of fat (Froese, 2006), or include insufficient sample size which have very narrow length size, can influence growth type determination. Furthermore, it is known that calculation with linear regression analysis on log-transformed data have some bias which come from nature of calculation methodology. There is some debate over the correct method of fitting such relationships and the estimation methodology may affected the result as a allometry (Packard, 2009; Kerkhoff and Enquist, 2009).

The sagittal otoliths were used to identify the age. We found that the large-scaled gurnard ranged up to age group VI; however, all previous studies reported the maximum age as IV (Colloca et al., 1997; Toğulga et al., 2000; Uçkun, 2005). This was a big difference and it was probably due to the regional, sampling timing and sampling differences. The growth of fish where they live is directly or indirectly affected by environmental conditions (supply of available food, temperature, and intensities of competition for food) and by fishing efforts (Weatherley and Gill, 1987). The age distribution showed that the dominant age was II and a similar result was given by Toğulga et al. (2000) for nearly the same study area as this study.

The theoretical maximal length value was calculated as a little greater than the size of the largest fish, and the growth coefficient value indicated relatively high attainment of maximal size. The growth analysis shows that more than half of their growth occurs in the first 2 years of their life span. The large-scaled gurnard attained 38.8% at the first year and 62.5% of the asymptotic size at the second year of their life. Similar results were also reported by Colloca et al. (1997). The infinite length (L_∞) was different from the findings of Toğulga et al. (2000), who reported the asymptotic length as 23.6 cm fork length for all samples. This result is relatively higher than ours and of all previous study findings. Furthermore, the maximum length was reported by Bauchot (1987) and Hureau (1986) as 20 cm total length. On the contrary, the minimum infinite length was reported by Colloca et al. (1997) as 11.7 cm standard length for all samples. The opposite condition was seen for the growth coefficient (*k*). The minimum value was reported as 0.132 y^{-1} by Toğulga et al. (2000) for all samples, and the maximum as 0.53 y^{-1} by Colloca et al. (1997) for males. The growth performance index (j') was calculated as 2.09 for our study and this parameter was calculated between 1.74 and 1.96 in previous studies. The *t*-test showed that there was no significant difference between the growth performance indexes in the other study areas (t = 0.056, $P > 0.05$).

The monthly average gonadosomatic index (*GSI*) reached the highest values of 6.11 for female and 0.82 for male in February. The male gonads were rather smaller than the female gonads and a similar result was also reported by Colloca et al. (1997). Although only one gonadosomatic index peak was shown for males, a second peak was shown in July, and third in October for females. Based on the gonadosomatic index values, the maximum spawning started in February and continued until June. Furthermore our observations show that the species have developing or ripe gonads in 9 months, which provide evidence of multiple spawning. It is well known that the spawning period has a close relationship with the ecological characteristics of the water system in which the species live. Hureau (1986) reported a spawning period from May to July. Colloca et al. (1997) reported that females with mature gonads were observed from April to September, but they did not observe mature gonads for males in the same period. Spawning period was reported as May by Toğulga et al. (2000). This result indicates that the species have a very short spawning period. However, this study and other studies' findings point out that the species is a partial spawner.

The batch fecundity results presented in this study represent the first estimation of reproductive potential of the large-scaled gurnard in the Aegean Sea. The oocyte diameters of the large-scaled gurnard ranged from 0.2 to 1.0 mm and similar findings were also reported by Toğulga et al. (2000). Our findings showed that the number of oocytes of these specimens ranged from 503 (age: 1+) to 10,046 (age: 6). This value was reported as 2426-7176 by Toğulga et al. (2000). Relationships between fecundity and fish size/weight indicate that the total number of oocytes per female increases with size and weight. It is well known that fecundity correlates significantly with fish length, weight, age, and gonad weight (Blaxter, 1969).

It was observed that the smallest female was 6.7 cm and the male was 6.2 cm total length. Colloca et al. (1997) reported minimum maturity size at 6 cm standard length in spring for female. The first maturity length was calculated at 10.55 cm total length for both sexes. The sexual maturity age was found to be at 2-years-old in both sexes. Similarly, Toğulga et al. (2000) and Hureau (1986) reported the first maturity age at 2-years-old. These findings show that the maturity length of the species does not change with different bio-ecological conditions.

In conclusion, the large-scaled gurnard (*Lepidotrigla cavillone*) is not a commercially important species in Turkish fisheries, but is a commercially and attractive fish species for some countries such as Italy (Colloca et al., 1997). The results of this work determine the length distribution, sex ratio, length-weight relationship, age, growth, spawning period, fecundity, first maturity age, and length features of the species and these findings provide information necessary for successful fisheries management.

Acknowledgments

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