

## Age, growth and reproduction of four-spotted goby, *Deltentosteus quadrimaculatus* (Valenciennes, 1837), in İzmir Bay (central Aegean Sea)

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**Abstract:** Length distribution, sex ratio, length-weight relationship, age, growth, spawning period, age, and length at first maturity of four-spotted goby inhabiting İzmir Bay were investigated. A total of 1696 four-spotted goby were collected by trawl hauls between July 2004 and June 2007. The size of the fish sampled ranged from 3.1 to 9.2 cm total length. The samples were composed of 31.1% females, 27.7% males, and 41.2% juvenile individuals, with a female to male ratio of 1:0.89. The age of the fish ranged from 1 to 5 years. The length-weight relationship and the von Bertalanffy growth function were estimated for all individuals as:  $W = 0.0036L^{3.45}$  and  $L_t = 10.29[1 - e^{-0.371(t + 0.502)}]$ . Spawning period started in February and continued until May. The lengths at first maturity of females and males were  $6.15 \pm 0.18$  and  $6.38 \pm 0.20$  cm total length, respectively.

**Key words:** Four-spotted goby, *Deltentosteus quadrimaculatus*, age, growth, reproduction, first maturity length, Aegean Sea

### İzmir Körfezi (Orta Ege Denizi) dört benekli kayabalığı'nın, *Deltentosteus quadrimaculatus* (Valenciennes, 1837), yaş, büyüme ve üreme özellikleri

**Özet:** Bu çalışmada, İzmir Körfezi'ndeki dört benekli kayabalığının boy dağılımı, cinsiyet oranı, boy-ağırlık ilişkisi, yaş, büyüme, yumurtlama dönemi, ilk eşeyssel olgunluk yaşı ve boyu araştırılmıştır. Temmuz 2004 ile Haziran 2007 tarihleri arasında İzmir Körfezi'nde yapılan trol çekimleri ile 1696 adet dört benekli kayabalığı elde edilmiştir. Örneklerin total boyları 3,1 ile 9,2 cm arasında değişmiştir. Elde edilen örneklerin % 31,1'inin dişi, % 27,7'sinin erkek ve % 41,2'sinin eşeyssel olgunluğa erişmemiş genç bireylerden oluştuğu ve stoğa ait eşey oranının 1:0,89 olduğu tespit edilmiştir. Örneklerin yaş kompozisyonunun 1 ile 5 yaşları arasında değişim gösterdiği tespit edilmiştir. Tüm bireyler için boy-ağırlık ilişkisi  $W = 0,0036L^{3,45}$  ve von Bertalanffy büyüme eşitliği  $L_t = 10,29[1 - e^{-0,371(t + 0,502)}]$  olarak bulunmuştur. Yumurtlama döneminin Şubat'ta başladığı ve Mayıs'a kadar devam ettiği belirlenmiştir. İlk üreme boyu dişilerde  $6,15 \pm 0,18$ , erkeklerde ise  $6,38 \pm 0,20$  cm olarak hesaplanmıştır.

**Anahtar sözcükler:** Dört benekli kayabalığı, *Deltentosteus quadrimaculatus*, yaş, büyüme, üreme, ilk üreme boyu, Ege Denizi

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## Introduction

Four-spotted goby, *Deltentosteus quadrimaculatus* (Valenciennes, 1837), is a member of the family Gobiidae. Its geographical distribution ranges from the Eastern Atlantic (26°N) to Mediterranean (19°N) (Froese and Pauly, 2009). Although its depth distribution was determined to reach 333 m (Mytilineou et al., 2005), it generally inhabits muddy bottoms with the 10-90 m depth range. It commonly feeds on polychaetes and natantian decapods (Lapropoulou and Markakis, 1998). Some of the amphipods and copepods such as *Longipedia scotti* composed the juvenile diet of this species (Tito de Moraes and Bodiou, 1984). The main predators of the species are john dory (*Zeus faber*) (Bell and Harmelin, 1983), tub gurnard (*Chelidonichthys lucernus*) (Morte et al., 1997), rufus snake eel (*Ophichthus rufus*) (Casadevall et al., 1994), four-spot megrim (*Lepidorhombus boschii*), and megrim (*Lepidorhombus whiffiagonis*) (Morte et al., 1999). It is considered a non-commercial species usually remaining in the discarded part of the bottom trawl catch (Machias et al., 2001). Studies carried out so far are limited to descriptions of the unusual pattern of the free neuromasts on the caudal fin (Ahnelt and Scattolin, 2005) and on length-weight relationships in the Balearic Islands (Merella et al., 1997), in the Mediterranean (Morey et al., 2003), in the north of the Aegean Sea (Lamprakis et al., 2003), and off the East Atlantic coasts of Spain (Mata et al., 2008).

This paper presents new information on population parameters such as length distribution, sex ratio, length-weight relationship, age, growth, spawning period, age, and length at first maturity of the four-spotted goby for the central Aegean Sea.

## Materials and methods

A total of 1696 four-spotted goby individuals were collected from trawl hauls taken from İzmir Bay (38°40'N 26°31'E and 38°2'N 26°8'E) by R/V Egesüf (26.8 m length, 463 HP engine, and 110 gross tons weight) from July 2004 through June 2007. The sampling was carried out at midday and the samples were collected at monthly intervals. The trawl surveys were performed using a traditional bottom trawl in 30 to 70 m depths on sandy and muddy bottoms.

The cod-end was knotless diamond-shaped mesh and made of polyamide (PA) material with 22 mm stretched mesh size. The towing durations were 1 h and the average towing speed was 2.3 knots (ranging between 2.2 and 2.4 knots).

All captured individuals were transported in ice to the laboratory for analyses. Total length ( $L$ ) of each individual 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. Sex was determined by macroscopic analysis of the gonads and 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 sex ratio (female:male) was calculated and a chi-square test was used to detect differences in the sex ratio. One-way ANOVA was done to check for 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 lengths and weights. The degree of association between the variables was estimated by the determination coefficient ( $R^2$ ). The growth type was identified by Student's t-test, which was applied to determine the significance of differences between the isometric growth ( $b = 3$ ) and allometric growth ( $b \neq 3$ ).

For the age determination, a total of 266 individuals were selected from each 0.5 cm size interval to represent all length groups. The sagittal otolith pairs were removed and cleaned, and stored in dry conditions inside the microplate. 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 macrostructure. Age estimations were made by 2 independent readers.

A von Bertalanffy growth function was fitted to size-at-age data using standard nonlinear optimization methods (Sparre and Venema, 1998). The function  $L_t = L_\infty[1 - e^{-k(t-t_0)}]$  was applied to the data where  $L_t$  is the fish length (cm) at the time  $t$  (year),  $L_\infty$  is the asymptotic length (cm),  $k$  is the

growth coefficient that describes the rate at which asymptotic length is approached ( $\text{year}^{-1}$ ), and  $t_0$  (year) is the hypothetical time at which the fish length was equal to zero. Munro's growth performance index ( $\varphi' = \log(k) + 2\log(L_\infty)$ ) was calculated to provide information for comparing fish growth with different populations (Pauly and Munro, 1984).

Spawning period was established from the variations of the monthly values of the gonadosomatic index (GSI) calculated as  $GSI = [W_g/(W - W_g)] \times 100$ , where  $W_g$  is the gonad weight (g) and  $W$  is the total weight (g) of fish (Ricker, 1975). Length at first maturity ( $L_m$ ) was defined as the length at which 50% of the population investigated is near to spawning (King, 1996). A logit function was used to assess the proportion of the mature individuals by size class using nonlinear regression (İlkyaz et al., 1998). The equations

$$r(l) = \frac{e^{a+bl}}{1 + e^{a+bl}}$$

and

$$L_m = \frac{-a}{b}$$

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.

## Results and discussion

During the study period, a total of 1696 individuals were sampled; 527 were females (31.1%), 470 were males (27.7%), and 699 were juveniles (41.2%). The sex ratio (female:male) was calculated as 1:0.89 and it was not significantly different from unity ( $\chi^2 = 3.26$ ,  $P > 0.05$ ), corresponding to what is observed for most fish species (Nikolsky, 1963).

The minimum size observed in December was 3.1 cm total length (Figure 1), corresponding to a weight of 1.3 g, while the maximum size found in November was 9.2 cm total length for a weight of 4.3 g. The smallest individual was reported as 4.2 cm for the Western Mediterranean (Morey et al., 2003), while the largest one was 10.3 cm for the north Aegean Sea (Lamprakis et al., 2003) in previous studies. This difference was probably due to the regional, sampling timing, and sampling gear differences. The average total length and total weight of the individuals were calculated as 7.08

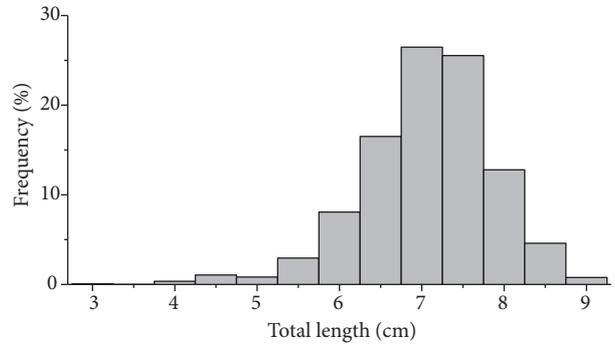


Figure 1. Total length-frequency distribution of the four-spotted goby (*Deltentosteus quadrimaculatus*) in the central Aegean Sea.

$\pm 0.02$  cm and  $3.28 \pm 0.03$  g ( $\bar{x} \pm \text{se}$ ), respectively. The average length of the females was  $7.17 \pm 0.03$  cm, and for males  $7.37 \pm 0.03$  cm; the ANOVA showed that average body length differed significantly between the sexes ( $F = 24.4$ ,  $P < 0.05$ ).

The overall length-weight equation was  $W = 0.0036L^{3.45}$ , while for females it was  $W = 0.0032L^{3.52}$  and for males  $W = 0.0049L^{3.29}$  (Figure 2). The  $b$ -values showed a significant difference in isometric growth for both sexes (for females 95% CI of  $b$  ( $CI_b$ ) = 3.44-3.61; for males  $CI_b = 3.19$ -3.40) and all fishes ( $CI_b = 3.41$ -3.50, t-test,  $P < 0.05$ ). The t-test results show that positive allometric growth was observed for males, females, and all fish. Results of studies carried out on the length-weight relationship of the species (Table) indicate that positive allometric growth has already been observed elsewhere.

Age of the four-spotted goby individuals ranged between 1 and 5. The age group 3 (38.5%) was dominant, followed by age groups 2 (33.1%), 4 (15.4%), 1 (7.1%), and 5 (5.9%). The four-spotted goby achieves a mean length of approximately  $4.40 \pm 0.16$  cm in the 1st year;  $6.27 \pm 0.10$  cm in the 2nd;  $7.47 \pm 0.06$  cm in the 3rd;  $8.26 \pm 0.04$  cm in the 4th;  $8.98 \pm 0.06$  cm in the 5th year ( $\bar{x} \pm \text{se}$ ). The asymptotic length ( $L_\infty$ ) 10.29 cm; the asymptotic weight ( $W_\infty$ ) was 11.29 g; the theoretical age of the fish prior to hatching from the egg ( $t_0$ ) was  $-0.502$  year; and the growth coefficient ( $k$ ) was  $0.371 \text{ year}^{-1}$  ( $R^2 = 0.995$ ). For all fish, the growth model was  $L_t = 10.29[1 - e^{-0.371(t + 0.502)}]$  and the growth performance

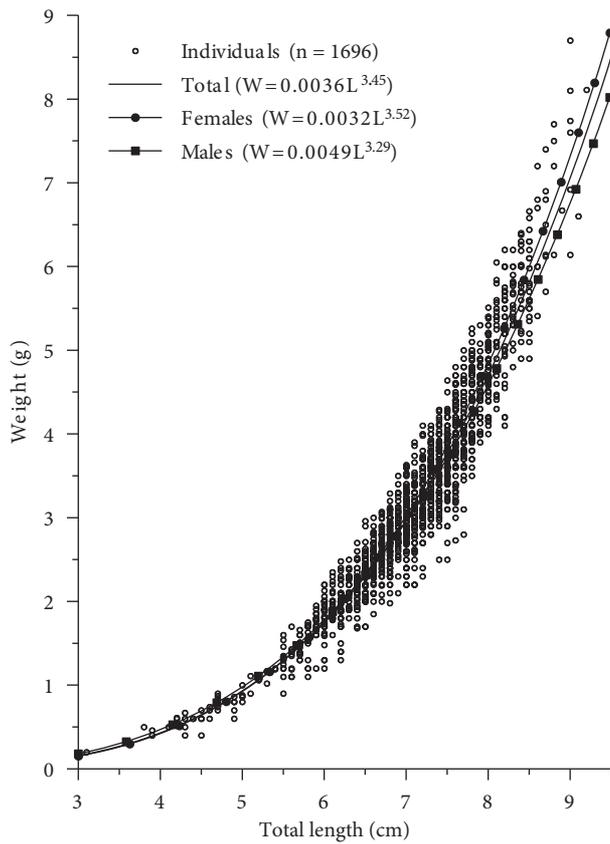


Figure 2. Length-weight relationships of the four-spotted goby (*Deltentosteus quadrimaculatus*) in the central Aegean Sea.

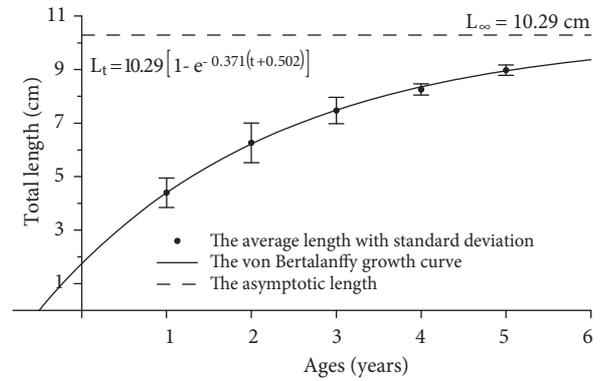


Figure 3. The von Bertalanffy growth curve of the four-spotted goby (*Deltentosteus quadrimaculatus*) in the central Aegean Sea.

index ( $\varphi'$ ) was 1.59 (Figure 3). The asymptotic length value was calculated as a little higher than the size of the largest fish, and the growth coefficient value indicated relatively rapid attainment of maximum size. The growth analysis shows that more than half of their growth occurs in the first 2 years of their life span. The four-spotted goby attained 42.8% of the asymptotic size during its 1<sup>st</sup> year and 60.9% by the 2<sup>nd</sup> year of their life. These calculated values are reported for the first time for four-spotted goby.

Monthly average gonadosomatic index (GSI) values of females and males are given in Figure 4.

Table. Length-weight relationships of the four-spotted goby (*Deltentosteus quadrimaculatus*) caught in İzmir Bay (the present study) and other different geographic areas. With  $n$ : number of specimens;  $L_{min}$ - $L_{max}$ : length range of specimens;  $a$  and  $b$ : intercept and slope of the relationship;  $R^2$ : coefficient of determination;  $\Sigma$ : sexes combined.

Author(s)	Sex	$n$	$L_{min}$ - $L_{max}$	$a$	$b$	$R^2$	Area
Marella et al. (1997)	$\Sigma$	28	7.0-9.2	0.0074	3.05		Balearic Islands
Lamprakis et al. (2003)	$\Sigma$	1010	4.3-10.3	0.0038	3.368	0.928	Thracian Sea (Greece)
Morey et al. (2003)	$\Sigma$	47	4.2-9.7	0.0022	3.6321	0.857	Balearic Islands and Iberian Peninsula
Mata et al.(2008)	$\Sigma$	53	5.0-7.5	0.008	3.23	0.91	Spanish South-Atlantic
The present study	$\Sigma$	1696	3.1-9.2	0.0036	3.45	0.940	
	♀	527	5.0-9.1	0.0032	3.52	0.924	İzmir Bay (Aegean Sea)
	♂	470	5.5-9.2	0.0049	3.29	0.889	

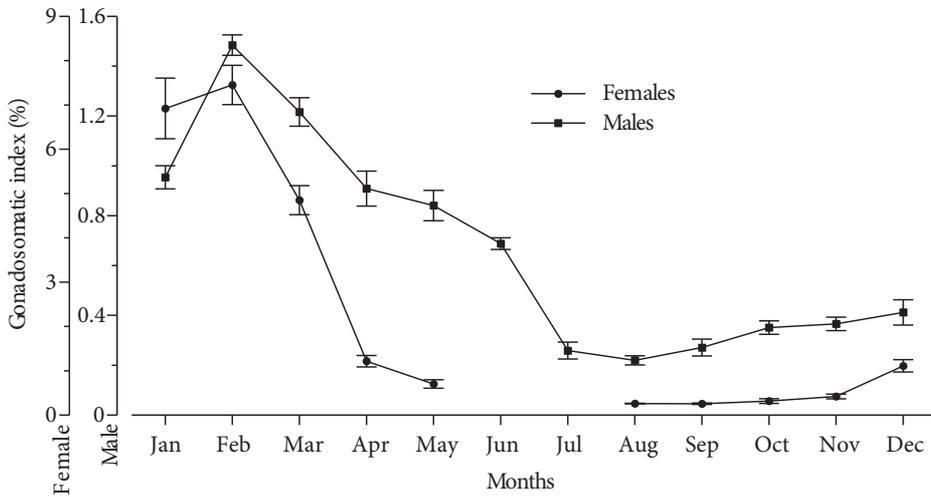


Figure 4. Monthly average gonadosomatic index (GSI) values (%) with standard error for females and males of the four-spotted goby (*Deltentosteus quadrimaculatus*) in the central Aegean Sea.

The male gonads were rather smaller than the female gonads. For both sexes, gonads start to mature in December and the maximum average gonadosomatic index value was observed in February for females ( $7.45 \pm 0.44$ ) and males ( $1.48 \pm 0.04$ , (GSI  $\pm$  se)). The male gonadosomatic index values show that the spawning period of the four-spotted goby started in February and continued until July. However, the female gonadosomatic index values indicated that the spawning period ended in May even if no female was caught in June and July. The spawning period of the four-spotted goby in the central Aegean Sea starts in February and continues until May. Similarly, reproduction period was reported by Miller (1986) to be between March and May in the Mediterranean, and other northeastern Atlantic and the Mediterranean gobies reproduction periods were reported between spring and mid-summer. This indicates that the spawning period, closely related with the ecological characteristics of the water system, is nearly same for the Mediterranean gobies.

It was observed that the smallest female and male were 5.0 and 5.5 cm total length respectively, both being 1 year old. Gonad maturity for 50% of the individuals ( $L_m \pm se$ ) was found to be  $6.15 \pm 0.18$  cm total length for females ( $a = -30.869$ ,  $b = 5.022$ ,  $R^2 = 0.912$ ) and  $6.38 \pm 0.20$  cm for males ( $a$

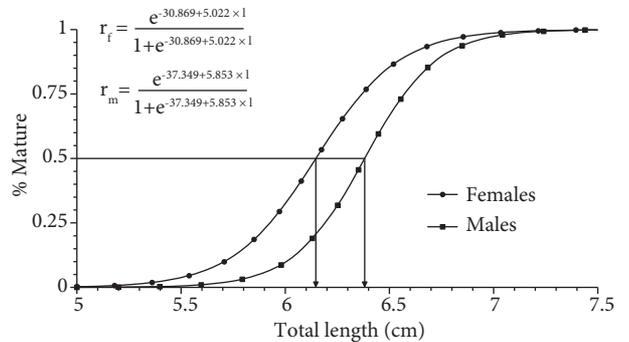


Figure 5. Estimation of the length at first maturity (vertical lines) of the four-spotted goby (*Deltentosteus quadrimaculatus*) for females and males in the central Aegean Sea.

$= -37.349$ ,  $b = 5.853$ ,  $R^2 = 0.945$ ) (Figure 5). These sizes correspond to individuals 2 years old for both sexes. The  $L_m$  values show that females reach the first maturity length earlier than males despite the same first maturity age. The average lengths also show that males were significantly larger than females. These differences may be explained by the better reproductive success of larger males shown by other goby species (Lindström and Hellström, 1993; Sasal et al., 1996; Kovačić, 2001) or the higher mortality rate in older females caused by greater reproductive effort than in males (Miller, 1984; Joyeux et al., 1991).

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