

RESEARCH ARTICLE

**Spatio-temporal patterns of abundance, biomass and length-weight relationship of white grouper, *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817) (Pisces: Serranidae) in the Gulf of Antalya, Turkey (Levantine Sea)**

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**Abstract**

The present paper reports the abundance and biomass of white grouper, *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817), (Pisces: Serranidae) according to depth levels and seasons in the Gulf of Antalya, and the length-weight relationship parameters of 350 individuals. A total of 116 hauls were carried out, between August 2009 and April 2010, seasonally in the Gulf of Antalya, at six stations and six depth levels (25, 50, 75, 100, 150, 200 m), using a commercial bottom trawl. *E. aeneus* was sampled from 60 hauls and the frequency of occurrence was 51.72%. The overall average biomass of *E. aeneus* was 55.78 kg/km<sup>2</sup> and the mean abundance was 60.60 ind./km<sup>2</sup>. The smallest total length (TL) was 10 cm and the maximum TL was 101 cm. The mean TL was calculated as 34.99 cm. The general length-weight relationship was described by the equation:  $W = 0.040 * L^{2.657}$  ( $r^2: 0.958$ ;  $p < 0.001$ ). Mean TL and weight of the specimens, *b*-value and mean biomass per abundance were highest in summer. The mean biomass per abundance was higher in Sts. D, E and F than Sts. A, B and C, located in the eastern part of the gulf. The mean abundance decreased as the depth level increased, however, mean biomass per abundance and mean TL and weight of the individuals increased constantly from 25 m to 100 m depth. The percentage of the mature fish decreased as the depth decreased.

**Key words:** *Epinephelus aeneus*, white grouper, seasonal trawl survey, Antalya, Mediterranean Sea, length-weight relationship.

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## Introduction

*Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817) can be found throughout the southern Mediterranean (up to 44°N in the Adriatic Sea) and along the west coast of Africa to southern Angola, including islands of the Gulf of Guinea (Thierry *et al.* 2008). Adults are found on rocky or mud and sand bottoms in depths of 20 to 200 m; juveniles have been found in coastal lagoons and estuaries (Heemstra and Randall 1993).

*E. aeneus* is of considerable economic importance in fisheries and caught with hooks and lines and by trawls. The species is listed as Near Threatened both in the Mediterranean Regional Red List and Global Red List of IUCN (Abdul Malak *et al.* 2011). The species is also reported to be an excellent candidate for mariculture because of the rapid growth rate and the potential for induced spawning in captivity and good results of aquaculture have been achieved in Israel (Hassin *et al.* 1997; Koven *et al.* 2007; Gorshkov 2010).

The maximum total length is reported as 120 cm and weight as 25 kg (Heemstra and Randall 1993). It is a protogynous hermaphrodite species that is reported to be mature first at 5 to 7 years, as a female (total length 50-60 cm, weight about 4kg) and sex change occurs at 10 to 13 years (total length 80-110 cm, weight 6-15 kg) in Tunisia (Bouain *et al.* 1983; Bruslé 1985). According to the Turkish national regulation on commercial fisheries (2/1), the minimum length of the capture of *E. aeneus* was 30 cm since 2011, and recently, it was changed to 45 cm and harvesting of smaller ones is prohibited by the regulation no. 2011/39.

Gökçe *et al.* (2003) studied the gonad histology and spawning pattern of this species in Iskenderun Bay (Turkey) and reported that the spawning period started in the beginning of June and continued till the end of August. According to the Turkish national regulation on commercial fisheries (2/1), all methods of grouper catching are prohibited between 15 June and 31 July. However, grouper catch with set longlines is permitted during this period on condition that the used fishhook is smaller than no. 9 (larger in size).

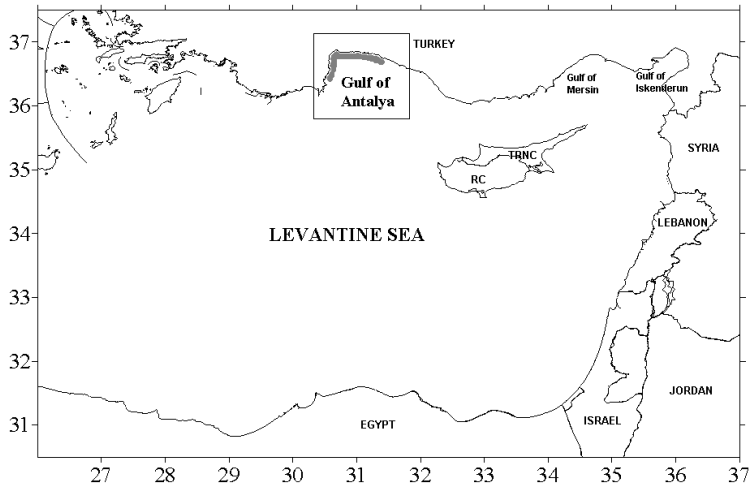
There has been no study on the spatial and temporal distribution of *E. aeneus* in Turkey. However, previously a few studies have reported the presence of *E. aeneus* in trawl hauls from Turkey (Başusta and Erdem 2000; Başusta *et al.* 2002; Çiçek *et al.* 2004) and CPUE and CPOA values for this species were reported by JICA (1993), Gücü and Bingel (1994), and Salihoğlu and Mutlu (2000).

## Materials and Methods

This research was carried out between August 2009 and April 2010, seasonally in the Gulf of Antalya, between the depths of 25-200 m, using a commercial bottom trawl.

### *Study Area*

The Gulf of Antalya is located in the Northeastern Levantine Basin and is characterized by high temperature, salinity and oligotrophy (Figure 1).

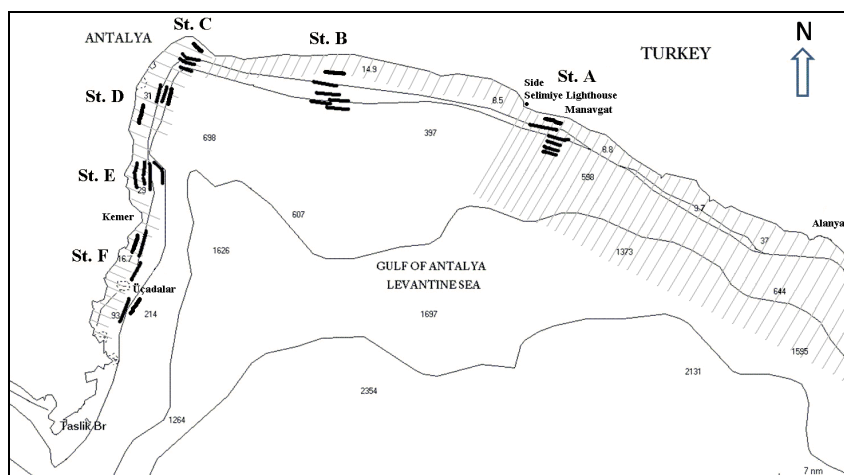


**Figure 1.** Map of the Gulf of Antalya-Turkey (Levantine Sea), showing the sampling area in grey color inside the rectangle (Turkish Republic of Northern Cyprus (TRNC), Republic of Cyprus (RC))

The geographical coordinates of 29 trawling areas at six stations vary between N36° 52' 48.5 - 36° 23' 00.0 - E31° 32' 32.2 - 30° 29' 48.8 (Figure 2). Samplings were carried out at six depth levels (25, 50, 75, 100, 150, 200 m) at St. A and B. Because of the narrow and steep continental shelf, trawling at 150 and 200 m depth levels, however, could not be realized at Sts. C, D and E, and 200 m at St. F. The research was conducted seasonally, both in “closed fishing” season (August 2009) and “open fishing” seasons (November 2009, February 2010, and April 2010) and in the no-trawl zones and open areas.

Turkish national regulation on commercial fisheries (2/1) covers a complex scheme of open/closed zones and seasons for trawl fisheries. Bottom trawling is prohibited during the fishing year within 2 NM off the coast and between 15 April and 25 September in the territorial waters where trawling is permitted.

Since 2005 till today, all sorts of trawling are prohibited in the territorial waters between Antalya Province, Side District, Selimiye Lighthouse (36°45,928' N-31° 23,092' E) and Alanya, Gazipaşa District, Kesik Cape (36° 09,964' N-32°23,418' E) where St. A is located and also the Manavgat River reaches the sea (covers the shaded area in Figure 2). The main commercial trawl area in the Gulf of Antalya is represented by St. B where two main streams reach the sea. Stations C and D are located off the Yacht Marina and Great Harbor of Antalya, respectively, and both are in the closed zones for trawl. Of Sts. E and F, 25 and 50 m depth levels are located within and 75, 100 and 150 m are outside 2 NM off the coast.



**Figure 2.** Map of the Gulf of Antalya-Turkey (Levantine Sea) showing the six sampling stations (named A, B, C, D, E, F from east to west) and the location and depth levels of 29 trawl hauls. The shaded areas show “no-trawl zones”.

### *Sampling Methods*

A total of 116 hauls were carried out at the depths of 25, 50, 75, 100, 150, 200 m, at six stations seasonally and duration of each haul was limited to an hour. Trawling was carried out by a commercial fishing vessel “Akyarlar” which was 24.80 m long with 450 HP engine. The cod-end mesh size was 22 mm (knot to knot). The samples were collected day time with 2.5 NM/h average towing speed.

*E. aeneus* specimens were identified, sorted from the total catches and counted. Subsequently, all fish obtained per station were measured (Total Length, TL) to the nearest 0.5 cm immediately after the capture, and weighed (Wet Weight, WW:  $\pm 1.0$  g). The specimens smaller than 30 cm TL were released back to the sea after measured and larger ones were donated to the governmental organizations after landed.

At each sampling station, physico-chemical characteristics were measured by a multiparameter probe (Hach-Lange HQ40D).

### *Data Analyses*

Mean seasonal values of chemical-physical variables were obtained for each station. The total catch from each haul was identified to species, counted, weighed and the stock amount was calculated according to the swept area method; the abundance and catch weight (Cw) divided by the swept area (a) for each species and for each haul (Spare and Veneme 1992).

The swept area (a) for each hauling was estimated thus:  $a = D.h.X$  (h: length of the head-rope, D: cover of distance, X: fraction of the head-rope length which was equal to the width of the path swept by the trawl (accepted as 0.5). The coordinates of the trawl operation was recorded by 30 seconds intervals by GPS and the cover of distance was calculated by summing the distances between the recorded coordinates.

Abundance (number of individuals per km<sup>2</sup>) and biomass (g per km<sup>2</sup>) per sampling were calculated, and the mean values were computed according to seasons, stations and depth levels. Length–weight relationships were assessed from measurement total wet weight (g) and total length (cm) and the curve parameters a and b were determined by *log*-transformation of raw data. Growth curves obtained from straight line for regression between total weight and length was:  $\log W = \log a + b * \log L$ , where W is the weight of the fish in grams (dependent variable), L is the total length in cm (independent variable), a is the regression constant related to body form and b is the regression coefficient indicating isometric growth when equal to 3. The theoretical equation of the length-weight relationship followed the power function of the form:  $W = aL^b$ , where W is wet weight (g) and L is total length (cm). This relationship was determined for the entire sampling seasons, stations and depth levels. To test the null hypothesis of the isometric growth ( $H_0: b = 3$ ), t-test was applied as expressed by the equation according to Sokal and Rohlf (1987):  $t_s = (b-3) / SE$ , where  $t_s$  is the t-test value, b the slope and SE the standard error of the slope (b). All the statistical analyses were considered at significance level of 5% ( $p < 0.05$ ).

Euclidean distance dissimilarity matrix, based on the log-transformed abundance and biomass, was tested by three-way orthogonal nonparametric (permutation-based) MANOVA (PERMANOVA) for assessing differences at seasons, stations and depth levels under a model in which all of them were fixed factors using PRIMER 6+ PERMANOVA software package (Anderson *et al.* 2008).

Differences in total length and weight of the specimens and mean biomass per abundance were tested among seasons, stations and depth levels by means of one-way Analysis of Variance (ANOVA). Fisher's LSD (Least Significant Difference) test was used for pairwise comparison among seasons, stations and

depth levels by using STATISTICA software package (Version 7; Statsoft, 2004).

Differences in slopes and intercepts of length-weight relationships between seasons, stations and depth levels were tested with Analysis of Covariance (ANCOVA). Departures of slope from the general length-weight relationship have been interpreted as a measure of differential body condition between size classes, i.e. steeper slopes meaning better condition of large individuals compared to smaller ones and vice versa. ANCOVA was performed using GraphPad Prism (Version 5, GraphPad Software 2007).

## Results

The sea water temperature was highly variable in the Gulf of Antalya seasonally (max. 32.8°C in August 2009 and min. 15.0°C in February 2010). Mean sea water temperatures were 28.83°C, 21.64°C, 18.02°C, and 18.80°C in summer, autumn, winter and spring, respectively. Increasing salinity from St. A to St. F indicated marked separation between the eastern and western parts of the Gulf. Mean salinity values were 33.76, 34.06, 38.10, 37.96, 38.14 and 38.75 psu in the Sts. A, B, C, D, E, and F, respectively.

During the entire research period, 369 individuals of *E. aeneus* were collected. Valid length-weight measures were taken, however, for only 350 individuals. It was sampled from 60 of 116 hauls and the frequency of occurrence was 51.72%. The highest abundance was found in St. A at 75 m depth in winter. The highest biomass was found in St. E at 75 m depth in winter. The abundance and biomass per km<sup>2</sup> of *E. aeneus* at six depth levels, six stations and in four seasons are shown in Table 1.

**Table 1.** The abundance (ind./km<sup>2</sup>) and biomass (kg/km<sup>2</sup>) of *E. aeneus* caught in the Gulf of Antalya according to depth levels, stations and seasons

St.	Depth	Abundance (Ind./km <sup>2</sup> )				Biomass (kg/km <sup>2</sup> )			
		Aug. 2009	Nov. 2009	Feb. 2010	Apr. 2010	Aug. 2009	Nov. 2009	Feb. 2010	Apr. 2010
A	25	649.33	663.41	265.81	71.2	199.93	101.06	35.12	12.6
A	50	177.21	-	107.92	-	56.54	-	218.54	-
A	75	29.72	10.52	707.92	-	101.04	15.77	116.81	-
A	100	16.27	35.97	-	-	81.37	187.07	-	-
A	150	-	-	-	-	-	-	-	-
A	200	-	-	41.42	-	-	-	2.49	-
B	25	119.91	246.82	41.42	82.85	20.92	57.15	2.07	7.25
B	50	10.05	28.48	75.95	17.99	5.53	2.85	51.9	1.8
B	75	7.35	-	-	-	3.31	-	-	-
B	100	-	41.42	-	-	-	69.39	-	-
B	150	-	-	-	-	-	-	-	-
B	200	-	-	-	-	-	-	-	-

Table 1. Continued

St.	Depth	Abundance (Ind./km <sup>2</sup> )				Biomass (kg/km <sup>2</sup> )			
		Aug. 2009	Nov. 2009	Feb. 2010	Apr. 2010	Aug. 2009	Nov. 2009	Feb. 2010	Apr. 2010
C	25	284.8	314.04	97.64	429.63	133.85	173.46	35.64	100.67
C	50	41.01	87.26	33.34	89.15	28.71	88.71	10.84	38.63
C	75	-	-	18.47	85.44	-	-	15.1em	60.52
C	100	-	-	31.07	47.14	-	-	27.96	34.18
D	25	25.32	203.21	18.99	88.19	12.66	56.34	2.85	17.64
D	50	13.14	-	208.02	-	139.33	-	277.12	-
D	75	-	-	-	56.96	-	-	-	406.31
D	100	17.75	70.1	-	-	23.52	484.59	-	-
E	25	59.44	370.23	-	99.68	22.29	44.86	-	12.32
E	50	29.72	-	77.38	85.44	82.47	-	84.73	62.25
E	75	68.35	116.34	130.19	-	384.82	403.56	776.27	-
E	100	65.72	46.34	-	30.38	395.65	180.72	-	185.31
F	25	-	-	-	13.14	-	-	-	11.17
F	50	73.23	-	15.9	-	123.89	-	46.1	-
F	75	-	-	25.79	-	-	-	69.64	-
F	100	-	-	-	12.9	-	-	-	64.48
F	150	-	-	-	-	-	-	-	-

The overall mean biomass ( $\pm$ se) of *E. aeneus* was 55.78 $\pm$ 10.88 kg/km<sup>2</sup> and mean abundance ( $\pm$ se) 60.60 $\pm$ 11.84 ind./km<sup>2</sup> (Table 2). The mean abundance per season ranged from 41.73 $\pm$ 15.43 ind./km<sup>2</sup> in spring to 77.04 $\pm$ 28.03 ind./km<sup>2</sup> in autumn. Abundance increased between summer and autumn and then decreased constantly towards spring (Table 2). The mean biomass per abundance was highest in summer; however, there was no difference seasonally ( $p > 0.05$ ).

Table 2. The mean abundance (ind./km<sup>2</sup>) and biomass (kg/km<sup>2</sup>) of *E. aeneus* caught in the Gulf of Antalya according to seasons (frequency of occurrence (F%), mean biomass/mean abundance (W/N))

Season	No. of hauls	Mean abundance		Mean biomass			F%	W/N
		( $\pm$ se) ind./km <sup>2</sup>	%	( $\pm$ se) kg/km <sup>2</sup>	%			
Summer	29	58.22 $\pm$ 24.14	24.0	62.61 $\pm$ 19.63	28.1	58.62	1.08	
Autumn	29	77.04 $\pm$ 28.03	31.8	64.33 $\pm$ 22.39	28.8	44.83	0.84	
Winter	29	65.42 $\pm$ 25.98	27.0	61.16 $\pm$ 28.35	27.4	55.17	0.93	
Spring	29	41.73 $\pm$ 15.43	17.2	35.00 $\pm$ 15.26	15.7	48.28	0.84	
Total	116	60.60 $\pm$ 11.84	100.0	55.78 $\pm$ 10.88	100.0	51.72	0.92	

The highest mean abundance was seen in St. A (115.70 $\pm$ 45.93 ind./km<sup>2</sup>), however the highest mean biomass in St. E (164.70 $\pm$ 54.91 kg/km<sup>2</sup>). St. F showed the lowest mean abundance (7.05 $\pm$ 3.85 ind./km<sup>2</sup>) and St. B the lowest

mean biomass ( $9.26 \pm 4.10 \text{ kg/km}^2$ ) (Table 3). The mean biomass per abundance was higher in Sts. D, E and F than Sts. A, B and C and difference among stations were statistically significant ( $p < 0.05$ ).

**Table 3.** The mean abundance (ind./km<sup>2</sup>) and biomass (kg/km<sup>2</sup>) of *E. aeneus* caught in the Gulf of Antalya according to stations (frequency of occurrence (F%), mean biomass/mean abundance (W/N))

St.	No. of hauls	Mean abundance		Mean biomass		F%	W/N
		(±se) ind./km <sup>2</sup>	%	(±se) kg/km <sup>2</sup>	%		
A	24	115.70±45.93	39.5	47.01±14.45	17.4	50.00	0.41
B	24	28.01±11.56	9.6	9.26±4.10	3.4	41.67	0.33
C	16	97.44±32.35	22.2	46.80±12.99	11.6	75.00	0.48
D	16	43.86±17.23	10.0	88.77±39.49	22.0	56.25	2.02
E	16	73.70±22.39	16.8	164.70±54.91	40.7	75.00	2.23
F	20	7.05±3.85	2.0	15.76±7.55	4.9	25.00	2.24

The mean abundance decreased as the depth level increased. The highest mean abundance was  $172.71 \pm 39.93 \text{ ind./km}^2$  at 25 m depth, while the highest mean biomass was seen at 75 m depth ( $98.07 \pm 39.94 \text{ kg/km}^2$ ) (Table 4). The mean biomass per abundance increased clearly from 25 m to 100 m depth and difference among depth levels were also statistically significant ( $p < 0.05$ ).

**Table 4.** The mean abundance (ind./km<sup>2</sup>) and biomass (kg/km<sup>2</sup>) of *E. aeneus* caught in the Gulf of Antalya according to depth levels (frequency of occurrence (F%), mean biomass/mean abundance (W/N))

Depth(m)	No. of hauls	ind./km <sup>2</sup> (±se)	%	kg/km <sup>2</sup> (±se)	%	F%	W/N
25	24	172.71±39.93	59.0	44.16±11.61	16.4	83.33	0.26
50	24	48.80±11.62	16.7	55.00±14.92	20.4	70.83	1.13
75	24	52.38±29.58	17.9	98.07±39.94	36.4	45.83	1.87
100	24	17.29±4.68	5.9	72.26±26.45	26.8	45.83	4.18
150	12	0.00±0.00	0.0	0.00±0.00	0.0	0.00	0.00
200	8	5.18±5.18	0.6	0.31±0.31	0.0	12.50	0.06

There was no difference in abundance and biomass among seasons; however the differences among depth levels and stations were statistically significant (Table 5).

Of 369 collected individuals, 350 were measured. The wet-weight of the smallest individual (10 cm) was 37.0 g. The maximum total length was measured as 101 cm (10.50 kg) and the wet-weight as 11.0 kg (97 cm). For the comparison of the length-weight relationship parameters with previous and future studies that have been or will be realized in different seasons, depths and areas, parameters were calculated separately for all seasons, stations and depth levels (Tables 6, 7 and 8). All relationships were highly significant ( $p < 0.001$ ). All R<sup>2</sup>-values were greater than 0.80.



The general length-weight relationship was described by the equation:  $W = 0.040 * L^{2.657}$  ( $r^2$ : 0.958;  $p < 0.001$ ; Table 6). Seasonal values of slope (b) ranged from a minimum of 2.523 in autumn to a maximum of 2.922 in summer (Table 6).

The difference in total length and weight of the specimens were statistically significant among seasons, stations and depth levels ( $p < 0.01$ ). According to the results of the Fisher's LSD (Least Significant Difference) test for pairwise comparison, there were seasonal differences only between summer and other seasons in total length and between summer-autumn and summer-spring in weight of the specimens. Mean TL and weight were highest in summer (Table 6; Figure 3). All the stations differed significantly from each other except for Sts. A-B and Sts. E-F in mean TL. Mean weight values were higher in Sts. D, E and F comparing to Sts. A, B and C and also St. D differed significantly from St. E (Table 7; Figure 3). The four depth levels (25, 50, 75 and 100 m) differed significantly from each other in mean TL and weight. Mean TL and weight increased constantly from shallow to deep waters (Table 8; Figure 3).

The results of ANCOVA (Table 9) showed that the slopes of the seasonal length-weight relationships differed significantly from each other (except for the pairs summer-spring and autumn-winter), showing a higher value in summer, then decreasing in autumn and increasing in winter and spring. The slopes of the LWR according to the depth levels differed significantly from each other (except for the pair 50-75 m). The  $b$ -value increased as the depth increased. Sts. A and B differed significantly from Sts. D and E, and St. C from St. E. The slopes of Sts. A and F were not different but intercepts were significantly higher in St. A. From east towards the western part of the Gulf, the mean TL and the  $b$ -value increased (Table 8).

In order to explore size related differences in spatial pattern, three size classes were formed, representing the immature (class 1: 10- 49 cm), mature female (class 2: 50- 79 cm) and mature male (class 3: 80- 101 cm) individuals, regarding the reference information (Bouain *et al.* 1983; Bruslé 1985) on the reproductive biology of *E. aeneus*. The highest percentage of the mature fish was at 100 m depth (44.4% females; 29.6% males) and the percentage decreased as the depth decreased. At 25 m depth level, 99.5% of the individuals were immature (Figure 4). At Sts. A, B, and C, more than 92% of the individuals were immature. The highest percentage of mature males was at St. E (26.2% females; 21.5% males) (Figure 5).

**Table 5.** Results of PERMANOVA for abundance (individuals per km<sup>2</sup>) and biomass (kg per km<sup>2</sup>) with seasons, stations and depth levels as fixed factors: bold number shows P<0.05

(df: degree of freedom, SS: sum of squares, MS: mean square, F: F-value, P (perm): calculated probability value; number of iterations = 1000)

Source	Abundance					Biomass			
	df	SS	MS	F	P (perm)	SS	MS	F	P (perm)
Season	3	1.6458	0.54859	0.22455	0.886	18.57	6.1899	0.31243	0.811
Station	5	60.393	12.079	4.9441	<b>0.002</b>	287.03	57.406	2.8975	<b>0.013</b>
Depth	5	154.39	30.877	12.639	<b>0.001</b>	626.49	125.3	6.3244	<b>0.001</b>
Seas. x St.	15	54.481	3.6321	1.4867	0.151	376.33	25.089	1.2664	0.215
Seas. x Depth	15	75.214	5.0143	2.0525	<b>0.027</b>	542.32	36.155	1.8249	0.051
St. x Depth	18	66.429	3.6905	1.5106	0.126	336.21	18.678	0.94279	0.55
Residual	54	131.92	2.443			1069.8	19.812		
Total	115	570.06				3468.6			

**Table 6.** Descriptive statistics and L-W relationship parameters for *E. aeneus* according to seasons

(N: sample size; TL = total length (cm); W: weight (g); min: minimum; max: maximum; S.D.: standard deviation; a = intercept; b = slope of the linear regressions; S.E.: standard error; C.I.: confidence interval; r<sup>2</sup> = coefficient of determination; GT = growth type (0 = Isometry, + = Positive allometry, - = Negative allometry))

Season	N	TL (cm)				W (g)				LWR parameters					GT
		Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	a	b	SE (b)	95% C.I. (b)	r <sup>2</sup>	
<b>Summer</b>	82	40.248	20.734	17.2	100.0	1,409.904	2,316.729	50.0	11000.0	0.015	2.922	0.053	2.817-3.028	0.974	0
<b>Autumn</b>	108	34.184	20.401	10.0	95.0	1,013.676	1,915.184	37.0	9500.0	0.065	2.523	0.049	2.426-2.620	0.962	-
<b>Winter</b>	89	33.131	21.443	14.0	97.0	1,089.438	2,165.884	50.0	10500.0	0.051	2.608	0.066	2.476-2.740	0.947	-
<b>Spring</b>	71	32.459	18.311	15.0	101.0	859.225	1,972.275	55.0	10500.0	0.021	2.824	0.056	2.714-2.935	0.974	-
<b>Total</b>	350	34.987	20.480	10.0	101.0	1,094.440	2,090.443	37.0	11000.0	0.040	2.657	0.030	2.598-2.715	0.958	-

**Table 7.** Descriptive statistics and L-W relationship parameters for *E. aeneus* according to stations

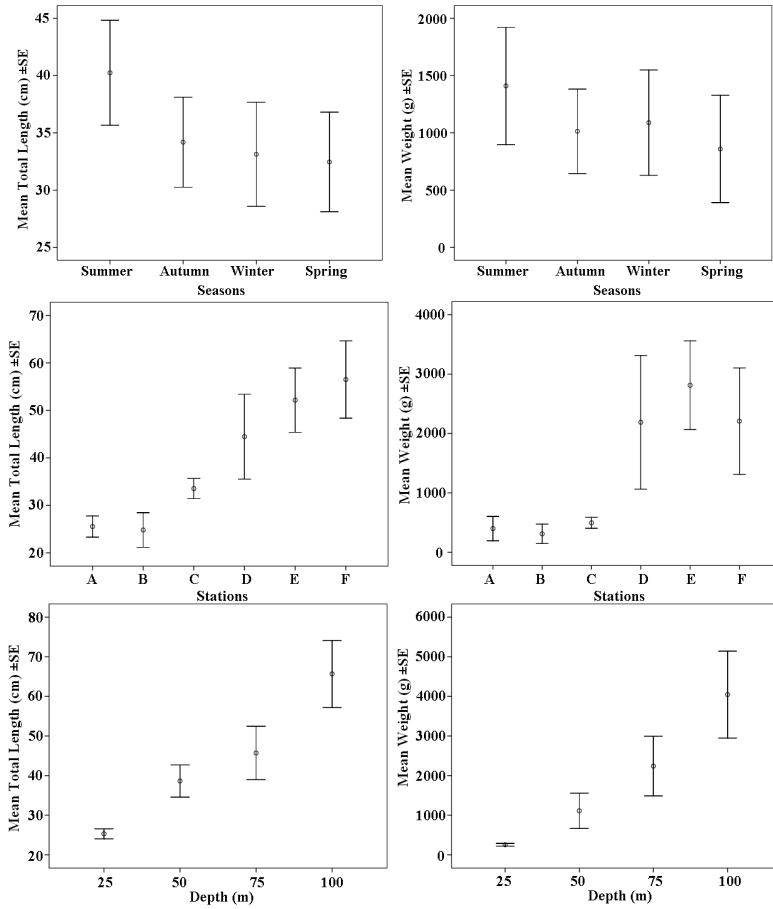
(N: sample size; TL = total length (cm); W: weight (g); min: minimum; max: maximum; S.D.: standard deviation; a = intercept; b = slope of the linear regressions; S.E.: standard error; C.I.: confidence interval;  $r^2$  = coefficient of determination; GT = growth type (0 = Isometry, + = Positive allometry, - = Negative allometry))

Stations	N	TL (cm)				Weight (g)				LWR parameters					GT
		Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	a	b	SE (b)	95% C.I. (b)	$r^2$	
<b>A</b>	126	25.546	12.506	10.0	95.0	398.683	1,147.964	37.0	10500.0	0.108	2.352	0.074	2.205-2.499	0.890	-
<b>B</b>	38	24.813	11.261	12.0	59.0	310.658	506.465	50.0	2750.0	0.105	2.363	0.111	2.138-2.587	0.927	-
<b>C</b>	75	33.543	9.131	15.0	60.0	496.733	400.719	100.0	2100.0	0.048	2.584	0.105	2.376-2.793	0.893	-
<b>D</b>	35	44.471	26.451	11.0	101.0	2,189.286	3,330.316	50.0	10600.0	0.022	2.830	0.085	2.657-3.003	0.971	0
<b>E</b>	65	52.155	27.286	17.5	97.0	2,812.846	3,013.437	55.0	11000.0	0.018	2.887	0.032	2.824-2.950	0.993	-
<b>F</b>	11	56.500	13.481	38.0	80.0	2,209.091	1,485.062	550.0	5000.0	0.009	3.028	0.183	2.614-3.442	0.968	0

**Table 8.** Descriptive statistics and L-W relationship parameters for *E. aeneus* according to depth levels

(N: sample size; TL = total length (cm); W: weight (g); min: minimum; max: maximum; S.D.: standard deviation; a = intercept; b = slope of the linear regressions; S.E.: standard error; C.I.: confidence interval;  $r^2$  = coefficient of determination; GT = growth type (0 = Isometry, + = Positive allometry, - = Negative allometry))

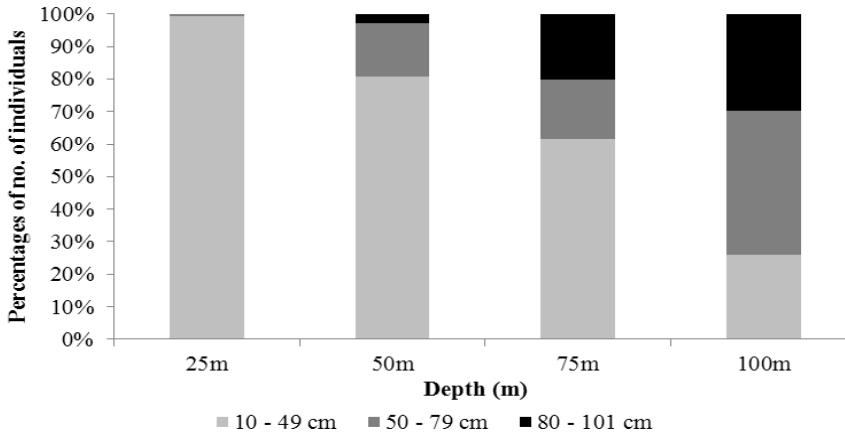
D (m)	N	TL (cm)				Weight (g)				LWR parameters					GT
		Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	a	b	SE (b)	95% C.I. (b)	$r^2$	
<b>25</b>	185	25.302	8.570	10.0	60.0	254.795	232.879	37.0	1650.0	0.197	2.159	0.060	2.040-2.278	0.875	-
<b>50</b>	73	38.636	17.376	15.5	100.0	1,110.440	1,909.215	75.0	10600.0	0.025	2.788	0.070	2.647-2.928	0.957	-
<b>75</b>	65	45.708	27.203	18.0	101.0	2,240.538	3,037.729	65.0	10500.0	0.017	2.891	0.032	2.828-2.954	0.993	-
<b>100</b>	27	65.674	21.973	16.7	97.0	4,045.185	2,850.083	50.0	11000.0	0.008	3.082	0.057	2.964-3.200	0.991	0



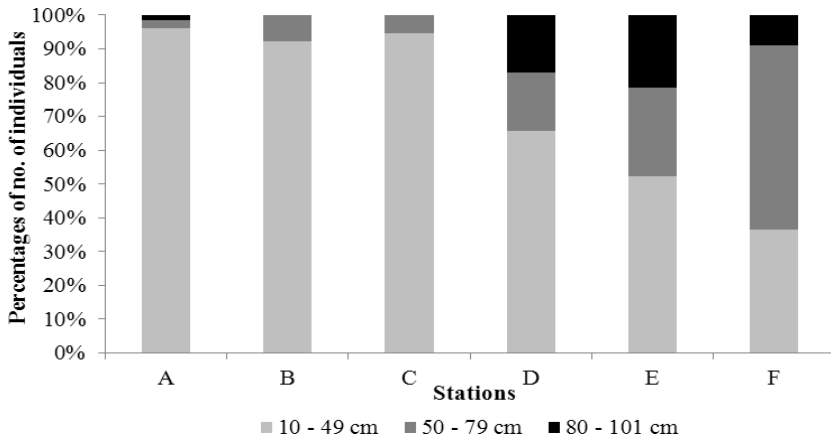
**Figure 3.** Mean total length (cm)  $\pm$  SE and mean weight  $\pm$  SE values according to season, station and depth levels

**Table 9.** Results of analysis of covariance (ANCOVA) showing pairwise differences between seasons, depth levels and stations of the length-weight relationships. Significant differences are indicated in the probability ( $p$ ) in bold.

ANCOVA - Comparison	Slope		Intercept	
	<i>F</i>	<i>p</i>	<i>F</i>	<i>P</i>
<b>Between Seasons</b>				
Summer-Autumn	27.424	<b>&lt;0.0001</b>		
Summer-Winter	12.319	<b>0.001</b>		
Summer-Spring	1.595	0.209	0.385	0.536
Autumn-Winter	1.114	0.293	0.900	0.344
Autumn-Spring	13.574	<b>0.000</b>		
Winter-Spring	5.043	<b>0.026</b>		
<b>Between Depth Levels</b>				
25m-50 m	42.334	<b>&lt;0.0001</b>		
25m-75 m	93.452	<b>&lt;0.0001</b>		
25m-100 m	54.195	<b>&lt;0.0001</b>		
50m-75 m	2.011	0.159	0.030	0.863
50m-100 m	6.721	<b>0.011</b>		
75m-100 m	7.627	<b>0.007</b>		
<b>Between Stations</b>				
St. A-St. B	0.005	0.942	0.058	0.810
St. A-St. C	2.686	0.103	0.315	0.575
St. A-St. D	16.985	<b>&lt;0.0001</b>		
St. A-St. E	39.349	<b>&lt;0.0001</b>		
St. A-St. F	2.865	0.093	5.141	<b>0.025</b>
St. B-St. C	2.183	0.143	1.246	0.267
St. B-St. D	10.891	<b>0.002</b>		
St. B-St. E	31.642	<b>&lt;0.0001</b>		
St. B-St. F	3.959	0.053	2.538	0.118
St. C-St. D	3.323	0.071	3.165	0.078
St. C-St. E	9.517	<b>0.002</b>		
St. C-St. F	1.938	0.168	2.223	0.140
St. D-St. E	0.583	0.447	0.108	0.743
St. D-St. F	0.315	0.578	0.393	0.534
St. E-St. F	0.521	0.473	1.577	0.213



**Figure 4.** The percentages of three size classes according to depth levels, representing the immature (class 1: 10–49 cm), mature female (class 2: 50–79 cm) and mature male (class 3: 80–101 cm) individuals, regarding the reference information (Heemstra and Randall 1993) on the reproductive biology of *E. aeneus*



**Figure 5.** The percentages of three size classes according to stations, representing the immature (class 1: 10–49 cm), mature female (class 2: 50–79 cm) and mature male (class 3: 80–101 cm) individuals, regarding the reference information (Heemstra and Randall 1993) on the reproductive biology of *E. aeneus*

## Discussion

*Epinephelus aeneus* is of considerable economic importance in fisheries and caught with spears, hooks and lines and in trawls in the Gulf of Antalya. Its abundance, biomass, size structure and LWR parameters varied seasonally and spatially. The selectivity of the trawl mesh-size affect the size distribution of the catch and the mesh size of cod-end (22 mm; knot to knot) that we use could have led to an underestimation of the overall population abundance. On the other hand, for the purpose of studying spatial and temporal patterns of population size structure and body condition, it is a useful sampling method.

There has been no study on the spatial and temporal distribution of *E. aeneus* in Turkey. Previously, the presence of *E. aeneus* in trawl hauls was reported from İskenderun Bay (Başusta and Erdem 2000), Yumurtalık Bay, Adana (Başusta *et al.* 2002), and from Babadillimanı Bight, Mersin (Çiçek *et al.* 2004).

JICA (1993) reported *E. aeneus* from the South Aegean Sea in the list of top 10 ranked species of fish with respect to CPUA ( $\text{kg}/\text{km}^2$ ) at the depth of 20-100 m in summer, 1991. The species was not included in the similar lists for the Sea of Marmara, North Aegean Sea or West and East Mediterranean Sea. Similarly, in the list of top 20 species of the highest biomass, Gücü and Bingel (1994) reported CPUE values of *E. aeneus* from some stations in İskenderun and Mersin Bays (NE Mediterranean Sea). Salihoğlu and Mutlu (2000) reported this species in the species lists of the trawl hauls in İskenderun and Mersin Bays and North Cyprus (NE Mediterranean Sea). For the comparison to the previous studies, the overall average biomass of *E. aeneus* was calculated both, according to the Catch per Unit Trawling Area ( $\text{kg}/\text{km}^2$ ) and Catch per Unit Trawling Effort (g/hour) for four depth levels (25, 50, 75, 100 m) and for overall depth levels, removing 150 and 200 m where the species was not frequently abundant (Table 10).

The highest biomass of *E. aeneus* for the NE Mediterranean Sea was reported from North Cyprus (Salihoğlu and Mutlu 2000). The present study reports the second highest biomass and the first detailed information on the spatial and temporal distribution of *E. aeneus* from the NE Mediterranean Sea.

**Table 10.** Comparison of the mean biomass of *E. aeneus* to the previous studies  
 CPUA= Catch per Unit Trawling Area (kg/km<sup>2</sup>); CPUE= Catch per Unit Trawling Effort (g/time))

Location	Date	Depth (m)	CPUA-CPUE	Source
S Aegean Sea	Summer, 1991	20-100	77 kg/km <sup>2</sup>	JICA 1993
İskenderun Bay- Turkey (NE Med. Sea)	Oct. 1983	15-35	4150 g/hour	Gücü and Bingel 1994
Mersin Bay- Turkey (NE Med. Sea)	Oct.1984	7-46	435 g/hour	Gücü and Bingel 1994
Mersin Bay- Turkey (NE Med. Sea)	Oct.1984	7-17	1192 g/hour	Gücü and Bingel 1994
Mersin Bay- Turkey (NE Med. Sea)	Oct.1984	25-45	418 g/hour	Gücü and Bingel 1994
Mersin Bay- Turkey (NE Med. Sea)	Nov. 1996	36-39	100 g/30 min	Salihoğlu and Mutlu 2000
İskenderun Bay- Turkey (NE Med. Sea)	Nov. 1996	40-46	60 g/30 min	Salihoğlu and Mutlu 2000
İskenderun Bay- Turkey (NE Med. Sea)	Nov. 1996	20-22	1200 g/30 min	Salihoğlu and Mutlu 2000
N Cyprus (NE Med. Sea)	Nov. 1996	83-90	10000 g/30 min	Salihoğlu and Mutlu 2000
Average of 14 hauls in İskenderun and Mersin Bays and North Cyprus (NE Med. Sea)	Nov.1996	14-90	874 g/hour	Salihoğlu and Mutlu 2000
Mersin Bay- Turkey (NE Med. Sea)	Sep. 1996	18-22	600 g/30 min	Salihoğlu and Mutlu 2000
Mersin Bay- Turkey (NE Med. Sea)	Dec. 1996	21-25	200 g/30 min	Salihoğlu and Mutlu 2000
Average of 5 hauls in Mersin Bay- Turkey	July- Dec.1996	0-25	160 g/30 min	Salihoğlu and Mutlu 2000
Average of 5 hauls in Mersin Bay- Turkey	July- Dec.1996	25-50	0	Salihoğlu and Mutlu 2000
Average of 4 hauls in Mersin Bay- Turkey	July- Dec.1996	50-100	0	Salihoğlu and Mutlu 2000
Average of 14 hauls in Mersin Bay- Turkey	July- Dec.1996	0-100	57 g/hour	Salihoğlu and Mutlu 2000
Mersin Bay- Turkey (NE Med. Sea)	Sep. 1998	50-75	70 g/30 min	Salihoğlu and Mutlu 2000
Average of 18 hauls in Mersin Bay- Turkey	April- Oct.1998	0-100	4 g/hour	Salihoğlu and Mutlu 2000
Average of 12 hauls in Mersin Bay- Turkey	March-June 1999	0-100	0	Salihoğlu and Mutlu 2000
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	25	44.16 kg/km <sup>2</sup> 3089.24 g/hour	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	50	55.00 kg/km <sup>2</sup> 3948.92 g/hour	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	75	98.07 kg/km <sup>2</sup> 6791.05 g/hour	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	100	72.26 kg/km <sup>2</sup> 4634.86 g/hour	Present Study
Average of 96 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	25-100	67.37 kg/km <sup>2</sup> 4616.01 g/hour	Present Study



The parameter b represents growth allometric rate, and indicates isometric growth when equal to 3. The slopes of length-weight relationships varied widely between ecosystems (Table 11). None of the studies, however, investigated its temporal and spatial fluctuations according to the size class, which indicate relative body condition between seasons, depth levels or stations. In this study, differences in allometric coefficients were recorded between seasons, depth levels and stations. While isometric growth was observed in summer, negative allometric coefficient was found in other three seasons. This suggested seasonal differences in size structure of the population. Smaller individuals showed a lower allometric coefficient while bigger individuals showed a higher coefficient. The overall value (2.657), on the other hand, was the lowest value compared to the previous studies, probably due to the higher abundance of the small size individuals in the present study. In addition, various factors may be responsible for the differences in parameters of the length-weight relationships among seasons, such as temperature, salinity, food (quantity, quality and size), sex, and stage of maturity (Pauly 1984; Weatherley and Gill 1987).

**Table 11.** Descriptive statistics and L-W relationship parameters for *Epinephelus aeneus* compared with previous studies

(N: sample size; TL = total length (cm); min: minimum; max: maximum; S.D.: standard deviation, \*standard error; a = intercept; b = slope of the linear regressions; GT = growth type (0 = Isometry, += Positive allometry, -= Negative allometry)

Study area	n	TL (cm)				LWR parameters		GT	Source
		Mean	S.D.	Min.	Max.	a	b		
Senegal-W. Africa						0.0053	3.230		1
Cape Verde-C. Atlantic Ocean	14			39.0	56.0	0.00168	3.580		2
Benin-W. Africa	9			18.6	68.0	0.0207	2.850		3
İskenderun Bay-Turkey (NE Med.)	89	34.26	10.97	17.40	67.5	0.0152	2.90	-	4
Turkey (NE Med.)	24	30.98	8.44	16.0	42.2	0.0120	2.987	0	5
Gökova Bay-Turkey (Aegean Sea)	36	21.0	0.45*	16.0	27.8	0.0098	3.043	0	6
Gulf of Antalya-Turkey (NE Med.)	350	34.987	20.480	10.0	101.0	0.040	2.657	-	7

Source: 1) Cury and Worms 1982, 2) Magnússon and Magnússon 1987, 3) Fiogbe 2003, 4) Can *et al.* 2002, 5) Sangun *et al.* 2007, 6) Ceyhan *et al.* 2009, 7) Present study

In this study, no data on the reproduction of this species were obtained because the samplings were carried out by a commercial fishing vessel and due to the lack of a special permission to land the groupers, the specimens under 30 cm TL were released back to the sea after measured and larger ones were donated to the governmental organizations after landed in accordance with the Turkish national regulation on commercial fisheries. Also, due to the limited time and lack of necessary conditions in the fishing vessel, gonads, otoliths or the stomachs of the fish could not be sampled.

Gökçe *et al.* (2003) reported the spawning period of *E. aeneus* to start in the beginning of June and continue till the end of August, in İskenderun Bay, Turkey (NE Mediterranean Sea), similar to the findings for *E. aeneus* and *E. marginatus* in Tunisia (Bouain and Siau 1983), Italy (Pelagic Islands, south Med. Sea) (Marino *et al.* 2001) and Spain (Zabala *et al.* 1997). Mean TL and weight of the specimens, *b*-value and mean biomass per abundance were highest in summer and it could possibly be related to the presence of mature individuals with higher gonado-somatic ratio.

Juveniles of *E. aeneus* tend to occur in coastal lagoons and estuaries (Heemstra and Randall 1993). In accordance to this, the mean biomass per abundance was higher in Sts. D, E and F than Sts. A, B and C which were in the eastern part of the gulf and the salinity was lower comparing to the west due to three main streams and Manavgat River reaching the sea. At Sts. A, B, and C, more than 92% of the individuals were immature. The highest abundance, represented by small individuals was sampled from the 25 m depth of St. A and the individuals with lowest mean TL were found in Sts. A and B. Any sort of trawling is prohibited in St. A since 2005 till today, however fishing with spears, hooks and lines are used to catch this species. Higher abundance and biomass in St. A compared to St. B, which is the main commercial trawl area of the Gulf, may be interpreted as the recovery of the “no-trawl zone”. The possible fishing effect can be seen in St. B with the lowest mean biomass, mean biomass per abundance and mean total-length value. Sts. C and D are closed zones for trawl, but popular areas for commercial and sportive fishing by hooks and lines due to their proximity to the Yacht Marina and Great Harbor of Antalya. The second highest abundance was found in St. C and the second highest biomass in St. D. The mean length values of both stations were higher than Sts. A-B, but lower than Sts. E-F. Although the depth levels of 75, 100 m of St. E and 75, 100, 150 m of St. F were located outside 2 NM off the coast due to the limited trawl area, the commercial trawlers generally do not prefer these regions for trawl. However, both stations are mostly preferred for small-scale fisheries. The highest biomass and mean individual weight were found in St. E, presenting the highest percentage of the mature males.

The mean abundance decreased as the depth level increased, however, mean biomass per abundance and mean TL and weight of the individuals increased constantly from 25 m to 100 m depth. The highest percentage of the mature fish was at 100 m depth and the percentage decreased as the depth decreased. At 25 m depth 99.5% of the individuals were at the size of immature fish. Similar distribution patterns of juvenile *E. marginatus* individuals in shallow and larger individuals in deeper waters were reported previously from the Mediterranean Sea (Bodilis *et al.* 2003a, 2003b; Foulquié and Dupuy de la Grandrive 2007).

In the Strait of Sicily, Bianchini *et al.* (2007) performed 3557 trawl hauls and reported that the catch of groupers was low both in number (27 fish, i.e. less

than 1 grouper per 120 h of fishing) and weight (275 kg, or 77 g/h in a fishery that catches over 50 kg/h). They found five species of groupers and six specimens of *E. aeneus* in three hauls, all at depths around 50 m with the largest specimen at 34.40 kg. They concluded that trawling did not seem to represent a significant risk for the grouper population of the Strait of Sicily because in general groupers live and take shelter in rough, untrawable grounds. However, the adults of *E. aeneus* are found on rocky or mud and sand bottoms in depths of 20 to 200 m and the high catchability rate of this species found in this study shows that trawling seem to represent a risk for the population of this species in the Gulf of Antalya.

Ünal *et al.* (2009) reported that 16% of the fishing operations throughout the season was focused especially on groupers in Gökova Bay. They recorded the total catch of all groupers as 1448 kg with a CPUE value of 3.78 kg per vessel and the ratio of groupers caught below legal size as 13.3% and immature individuals as 85%. *E. aeneus* constituted 11% of the total landing volume and the highest economic value (31%) in Gökova Bay, 2006. They mentioned the insufficient scientific studies to prepare a sustainable management of groupers and suggested to determine the reproduction areas and declare these areas “No Take Zones” which is going to affect positively not only the species but also whole ecosystem they live in. Similarly, Lakkis and Sabour (2007) reported a decrease in the grouper stocks in the Syrian and Lebanese coastal waters and highlighted the importance of protected areas and marine reserves together with the regulations in fishing activities.

Thiao *et al.* (2012) recently reported the collapse of *E. aeneus* stock due to the booming small-scale fishery sector in Senegal and mentioned the necessity of a balance between conservation and exploitation to maintain ecological viability while considering the socio-economic importance of the small-scale fisheries.

There is no closed area or season for longline and gillnets in the Gulf of Antalya and species selectivity is impossible with the currently used gears. Although, using speargun, fish trap, fyke nets etc. are prohibited to catch groupers, illegal fishing is practiced. Ünal *et al.* (2009) reported that the amount of illegally caught groupers is almost equal or larger than the legal annual catch amount in Gökova Bay. Therefore, land-based combating was advised as a more effective and low-cost solution. More detailed studies are necessary on the biology and ecology of this species in the region; however, this is so far the most detailed study on spatio-temporal distribution and length-weight relationship of *E. aeneus* in Turkey. The results of this study are expected to be useful for future decisions on declaration of “No Take Zones” or protected areas in the Gulf of Antalya.

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## Antalya Körfezi’nde Kum gridası, *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817) (Pisces: Serranidae)’un bolluk, biyokütle ve boy-ağırlık ilişkisinin mevsimsel ve mekansal değişimi

### Özet

Bu çalışmada, *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817), (Pisces: Serranidae)’un, Antalya Körfezi’nde mevsim, istasyon ve derinliklere göre bolluk ve biyokütlesi ve elde edilen 350 bireyin boy-ağırlık ilişkisi bildirilmektedir. Ağustos 2009-Nisan 2010 tarihleri arasında mevsimsel olarak, altı istasyonda ve altı farklı derinlikte (25, 50, 75, 100, 150, 200 m), toplam 116 trol çekiminin 60’ında (% 51,72) *E. aeneus* örneklenmiş olup, ortalama bolluk 60,60 birey/km<sup>2</sup>, biyokütle ise 55,78 kg/km<sup>2</sup> olarak hesaplanmıştır. En küçük birey 10 cm ve en büyük total boylu (TB) birey 101 cm ölçülmüş olup, ortalama total boy 34,99 cm hesaplanmıştır. Boy-ağırlık ilişkisine ait denklem,  $W = 0.040 * L^{2.657}$  ( $r^2: 0.958$ ;  $p < 0.001$ ) olarak ifade edilmiştir. Bireylerin ortalama TB ve ağırlığı, *b*-değeri ve ortalama biyokütle/bolluk yazın en yüksektir. İstasyon D, E ve F’de ortalama biyokütle/bolluk, körfezin doğusunda bulunan istasyonlara (İst A, B, C) göre daha yüksektir. Derinlik arttıkça, ortalama bolluk azalmış, fakat, ortalama biyokütle/bolluk ve bireylerin ortalama TB ve ağırlığı 25 m’den 100 m’ye doğru gittikçe artmıştır. Ergin bireylerin yüzdesi, derinlik azaldıkça azalmıştır.

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