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RESEARCH ARTICLE

Some population parameters of *Scyliorhinus canicula* (Linnaeus, 1758) from the northeastern Mediterranean Sea

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Abstract

A total of 1150 lesser spotted dogfish (*Scyliorhinus canicula* L., 1758), (562 female, 588 male) were collected by commercial trawlings in depths of 155-400 m in the Northeastern Mediterranean Sea between March 2012 and May 2014. Total length and weight of the fish were ranged from 12.0 to 51.0 cm and 4.13 to 396.0 g, respectively. It was determined that female/male ratio was 1:1.2. Monthly length frequency data of *S. canicula* were analyzed using FISAT II for estimating population parameters, including asymptotic length (L_∞), growth coefficient (k) and recruitment pattern to assess the status of the stock. The parameters of von Bertalanffy growth equations were estimated as L_∞=56.70 cm, K=0.20 year^{-1} and t_0= -1.60 year and W_∞= 622.01 g. The growth performance index (Φ') value was calculated as 2.808. Length-weight relationships was found to be $W=0.0013*L^{3.239}$ (R^2=0.97), SE of b=0.016 and 95 % confidence intervals of b = 3.209-3.271. The type of growth shows positive allometric growth ($b>3$). Catch rates were calculated as 34.94 cm for females and 35.04 cm for males. Instantaneous mortality coefficient, natural mortality (M), fishing mortality coefficient (F) and total mortalities (Z) exploitation rate were estimated of *S. canicula* as Z = 1.06 year^{-1}, M = 0.47 year^{-1}, F = 0.59 year^{-1}. The exploitation rates (E) was determined as 0.56 year^{-1}. Therefore on the *S. canicula* distributed in Iskenderun Bay were under fishing pressure.

Keywords: *Scyliorhinus canicula*, growth, length-weight relationships, mortality, catch rate

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Introduction

The genus *Scyliorhinus* (family Scyliorhinidae), often called lesser spotted dogfish, includes 25 species world-wide, two species inhabiting in the Mediterranean (*S. canicula* and *S. stellaris*), both in the eastern basin. *S.*

canicula inhabits soft or hard substratum, often covers with algal meadows at depts of 50-400 m. Spawning season takes place from November to June. Schools of females reach their reproductive site at the beginning of winter; the males join them a few months later (Golani *et al*. 2006). The main prey groups for *S. canicula* are crustaceans and fishes in the Northeastern Mediterranean (Ozcan and Başusta 2015). There are some biological studies on lesser spotted dogfish from different regions, with an exception of the northeastern Mediterranean (Cihangir *et al*. 1997; Filiz and Mater 2002; Filiz and Bilge 2004; Filiz and Taşkavak 2004; Ozaydın *et al*. 2007; Kınacıgil *et al*. 2008; Turker-Cakir *et al*. 2006; Ismen *et al*. 2009; Demirel and Dalkara 2012; Güven *et al*. 2012; Moutopoulos *et al*. 2013; Ozcan and Başusta 2016). The aim of this study was to determineage, growth, length-weight relationships and reproduction of *S. canicula* population living in the northeastern Mediterranean Sea for the first time.

Materials and Methods

A total of 1150 specimens of *S. canicula* were collected by commercial trawling operations between March 2012 and May 2014 (36° 16' 622" N – 035° 18' 509" E; 36° 06' 408" N – 035° 22' 208" E) in the Northeastern Mediterranean Sea (Figure 1). Fish samples were transported to the laboratory of Fisheries Faculty at Firat University, Elazığ (Turkey). Species identification was made following to Golani *et al.* (2006). For each specimens sex determined and total length (*TL*) was measured to the nearest 0.1 cm, total weight to the nearest 0.1 g. Length-frequency data were analyzed using FiSAT (Gayanilo *et al*. 1996).

Figure 1. The study area shown by a circle in the northeastern Mediterranean Sea

Estimates of theoretical growth in length were obtained by using FiSAT II package program (http://www.fao.org/fishery/topic/16072/) by fitting von

Bertalanffy Growth Function (VBGF) (v. Bertalanffy 1938) to the mean lengths at estimated age: $TLt=TL\infty[1-e^{-K(t-t0)}]$. *TLt* is the expected total length at age *t* years, $TL\infty$ is the asymptotic average maximum total length, *K* is the growth coefficient, and t_0 is the theoretical age at zero length.
$Log\ (-t_0) = (-0.3922) – 0.2752\ log\ L\infty - 1.038\ log\ K$ (Pauly 1984).

Growth rate (K), asymptotic length ($L\infty$) and growth performance index (Φ) of the fish was assumed to follow von Bertanlaffy Growth Function.

Accuracy of the growth parameters was tested using Munro's growth performance index (Pauly and Munro 1984): $Ø=log10(K)+2log10(L\infty)$; *K* and $L\infty$ are the von Bertalanffy's growth parameters.

To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to the goodness-of-fit tests by assessing the ratio ESP/ ASP (Rn). Data analysis was conducted with the most recent version of FISAT (Gayanilo & Pauly, 1997) statistical software. Electronic length frequency analysis (ELEFAN) (Pauly *et al*. 1984) was used to estimate the parameters. The instantaneous rate of natural mortality (M) was obtained using Pauly's empirical formula (Pauly, 1983):

$In\ M = -0.0152 -0.279\ x\ In\ L\infty + 0.6543\ x\ In\ K + 0.463\ x\ In\ T$

The instantaneous rate of total mortality (Z) was found from the estimate of the growth parameters (K, $L\infty$), using the length converted catch equation (Pauly *et al*. 1984). The instantaneous rates of fishing mortality (F) were calculated by the subtraction of the estimates of M from Z: $F=Z-M$
The exploitation rate was calculated as follows: $E = F / Z$.

The relationship between length and weight was calculated using $W = a*L^b$, where *W* is total weight (TW, g), *L* total length (TL, cm), *a* intercept of the regression and *b* slope or regression coefficient. The *b* values of both sexes for *S. canicula* was tested by using the Kolmogorov-Smirnov two-sample test, and *b* value variation from 3 was tested with one sample t-test ($P<0.001$). The degree of association between the variables was computed by determination coefficient, R^2 (King 1995).

Results

A total of 1150 specimens (562 females and 588 males) were collected during the study period. Total length and weight of sampling varied from 12.0 to 51.0 cm and from 4.13 to 396.0 g, respectively (Figure 2). The total length-weight frequency distribution is given in Figure 2 and Table 1. The female to male ratio was determined as 1:1.2.

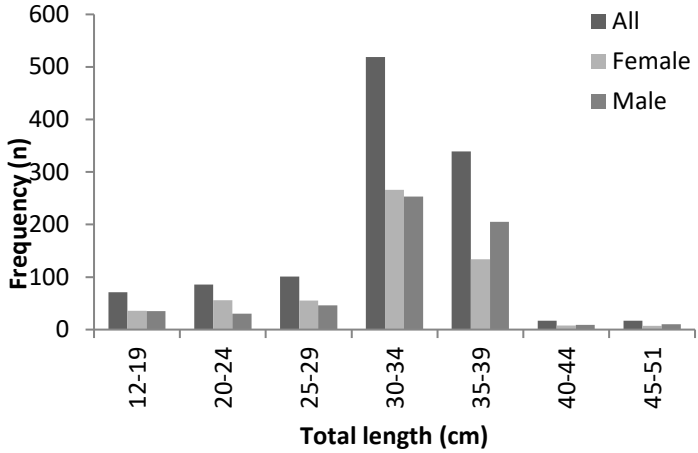

Figure 2. Total length-frequency data of *S. canicula* from the northeastern Mediterranean Sea

Table 1. Monthly total length and weight of *S. canicula* from the Northeastern Mediterranean Sea

		Total Length (cm)				Weight (g)			
Months	**N**	**Min**	**Max.**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**
May-2011	2	49.2	51.0	50.1	0.521	366	396	381	8.717
March-12	3	31.9	35.6	33.5	1.08	90.7	128.1	107.2	11.01
April-12	3	34.5	47.0	41.2	3.63	103.3	312.0	221.7	61.87
May-12	29	29.4	51.0	34.5	0.88	54.1	396.0	126.4	13.53
June-12	124	15.6	38.5	31.5	0.305	9.2	156.3	93.4	2.57
July-12	36	29.7	41.0	34.8	0.508	54.1	228.0	101.68	6.75
September-12	37	29.8	44.0	35.2	0.382	82.4	276.0	122.5	5.57
October-12	18	17.1	48.0	34.4	1.304	14.6	330.0	128.5	14.13
November-12	21	32.4	40.0	35.1	0.46	96.6	212.0	131.9	6.96
December-12	63	23.1	45.0	33.6	0.41	31.7	290.0	120.7	5.06
January-13	94	28.3	50.0	34.2	0.29	67.0	84.0	125.3	4.36
March-13	104	19.9	39.5	31.4	0.33	24.8	156.2	97.6	3.10
April-13	70	28.3	49.0	33.9	0.44	61.9	346.0	122.3	6.12
May-13	37	29.8	40.0	33.9	0.39	81.4	210.0	125.7	5.42
June-13	372	12.0	48.7	29.1	0.32	4.10	332.0	82.8	2.46
July-13	6	34.0	46.0	37.1	1.85	111.3	302.0	167.4	28.02
Auğust-13	8	31.1	49.0	37.8	1.98	115.0	345.0	183.2	27.8
January-14	4	31.8	34.4	33.0	0.54	111.7	129.2	120.6	4.02
February-14	87	12.1	47.0	25.2	0.91	4.40	313.0	63.4	7.25
March-14	2	32.7	42.0	37.4	4.65	127.0	250.0	188.5	61.46
May-14	32	12.6	37.2	29.7	1.37	4.30	177.7	92.3	8.84

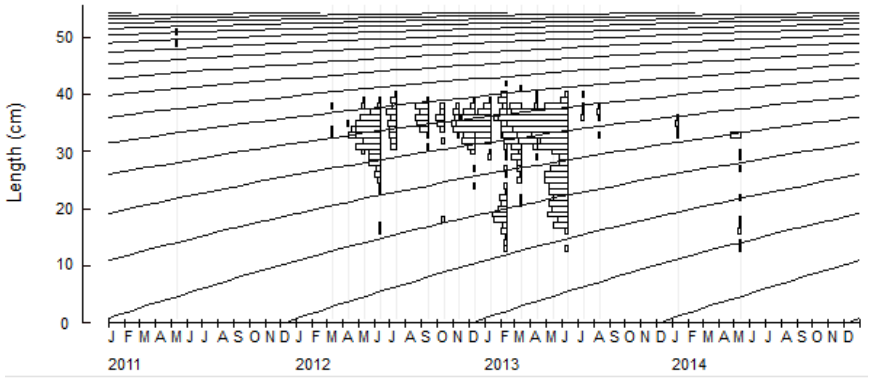

Figure 3. Monthly the length-frequency distribution and von Bertalanffy's length growth curves for all sexes of *S. canicula*

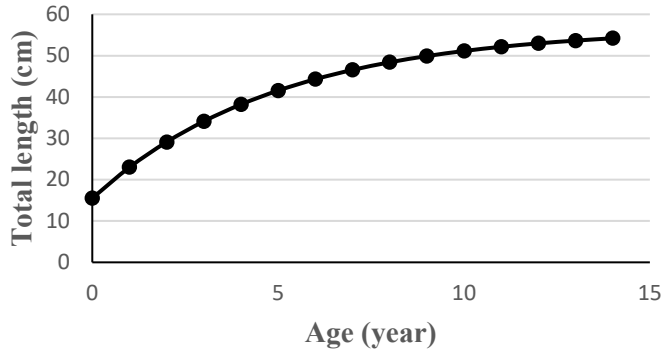

Figure 4. Age-length relationship of *S. canicula* for combined sexes

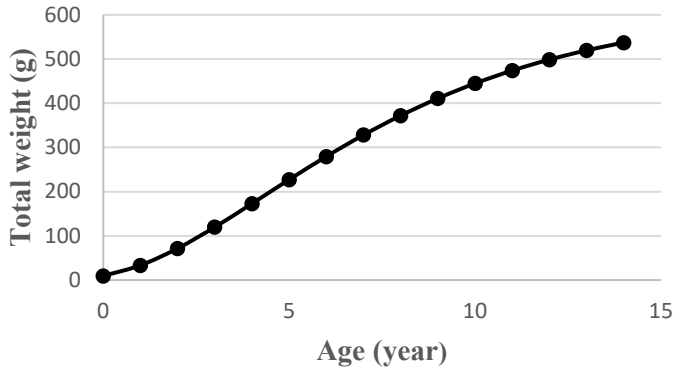

Figure 5. Age-weight relationship of *S. canicula* for combined sexes

The growth parameters L∞ and K in were obtained for the best fit with $TL\infty$ = 56.70 cm and K = 0.20 year^{-1}, goodness of fit index (Rn) = 0.230 (Figure 3). Monthly the length-frequency distribution and von Bertalanffy's length growth curves for all sexes of *S. canicula*. Age-length and age-weight relationships for all sexes of *S. canicula* were given in Figure 4. The growth performance index (Φ') value (all individuals) was computed as 2.808.

The total length data were entered in the FISAT II ICLARM package program and a graph were created by using the Normsep Algorithm Method. In this graph, the peak points represents the age groups. In addition, this graph gives frequency and mean total lengths for each group. The age composition of *S. canicula* varied between 0 and 14 (Table 2). Catch rates were calculated as 34.94 cm in females and 35.04 cm in males (Figure 6).

Table 2. Average total length and weight at age for *S. canicula* from the northeastern Mediterranean

Age	Total length (cm)	Weight (g)
0	15.52735	9.373626
1	22.99068	33.42027
2	29.10115	71.70479
3	34.10397	119.8667
4	38.19994	173.0789
5	41.55343	227.306
6	44.29904	279.6497
7	46.54695	328.2789
8	48.38739	372.2124
9	49.89421	411.0813
10	51.12789	444.9243
11	52.13794	474.0288
12	52.9649	498.8168
13	53.64196	519.7672
14	54.19629	537.3667

Length and weight measurements, sample sizes (n), regression parameters *a* and *b* of the LWR, 95% confidence intervals of *b* and coefficients of determination (R^2) of the *S. canicula* were given in Table 3. The calculated *b* value indicates positive allometry ($b>3$) and the coefficient of determination (R^2) was 0.97 (Figure 7). Regression analysis showed that fish length has high significant correlation with weight ($R = 0.99$, $R^2 = 0.97$, $F_{1, 1148} = 41990.595$, $P < 0.001$) and it is possible to say that 97% increase in weight was due to length increase. Normality test was done by using the Kolmogorov-Smirnov two-sample test. When the t-test results were analyzed for the significance of regression

coefficients (t-test = 204.916, P <0.01), it was found that fish-length data could be used in high accuracy to predict fish weight.

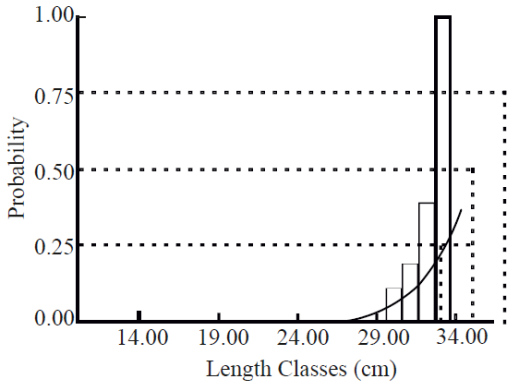

Figure 6. Catch rates of *S. canicula* obtained by using FISAT II from the northeastern Mediterranean Sea

Table 3. Length-weight relationships for *S. canicula* in the northeastern Mediterranean (n: number of individuals, *a*: intercept, *b*: slope, *CI*: confidence intervals of *b*, R^2: coefficient of determination)

Sex	**n**	**Size range (cm)**	**Weight range (g)**	***a***	***b***	***95% CI of b***	***R^2***
Female	532	12.0-49.2	4.1-366.0	0.0009	3.347	3.31-3.38	0.98
Male	618	17.1-51.0	4.4-396.0	0.0015	3.169	3.12-3.21	0.97
All	1150	12.0-51.0	4.1-396.0	0.0013	3.239	3.20-3.27	0.97

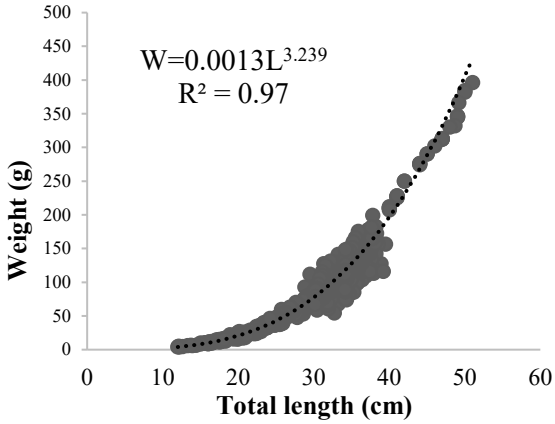

Figure 7. Length-weight relationships of *S. canicula* from the northeastern Mediterranean

Instantaneous mortality coefficient, natural mortality, fishing mortality coefficient and exploitation rate were estimated of *S. canicula* Z = 1.06 year^{-1}, M = 0.47 (at 21.9°C), F = 0.59 and E = 0.56 (Figure 8).

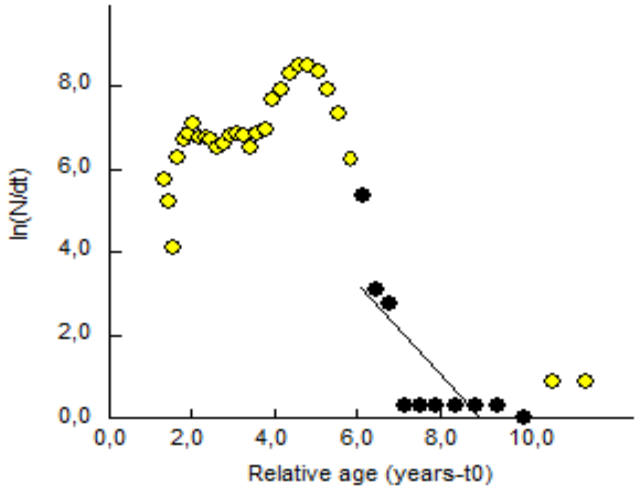

Figure 8. Instantaneous mortality coefficient from Length-Converted Catch Curve

Discussion

In this study, total length and weight ranged from 12.0 to 51.0 cm and from 4.13 to 396.0 g, respectively in the Northeastern Mediterranean. The average length and weight were calculated as 29.6 cm and 110.9 g, respectively. Average length and weight values were 29.1±0.24 cm and 114.0±0.59 g for females, 30.3±0.21 cm and 108.4±2.60 g for males. These results indicated that males had higher averages in terms of length and weight than females in general.

Length–weight relationships may show temporal or spatial variations due to their size range, reproductive activities and stage or environmental factors such as water temperature, food quality and availability, diseases, and competition (Wootton 1990). The results of this study could give useful insight for management and conservation of *S. canicula* in Turkish waters. The comparison of the total length–weight relationships of *S. canicula* (Table 4) shows the differences between the patterns of growth across regions. The differences can be attributed to the combination of several factors such as sample size, sampling date, sampling methods.

Table 4. Length-weight relationships for *Scyliorhinus canicula* in in different regions

Region	n	*a*	*b*	R^2	References
North Aegean Sea	586	0.0010	3.20	0.91	Cihangir *et al.* (1997)
North Aegean Sea	113	0.0016	3.18	0.97	Filiz and Mater (2002)
North Aegean Sea	637	0.0012	3.26	0.99	Filiz and Bilge (2004)
The Bay of Izmir	187	0.0006	3.43	0.95	Ozaydın *et al.* (2007)
Aegean Sea	744	0.0010	3.28	0.95	Kınacıgil *et al.* (2008)
The Bay of Edremit	112	0.0020	3.09	0.86	Turker Cakir *et al.* (2008)
The Gulf of Saroz	1888	0.0017	3.17	0.97	Işmen *et al.* (2009)
Marmara Sea	189	0.0040	2.86	0.86	Demirel and Dalkara (2012)
Antalya Bay	647	0.0012	3.27	0.96	Güven *et al.* (2012)
The Gulf of Korinthiakos	11	0.0019	3.13	0.93	Moutopoulos *et al.* (2013)
The northeastern Mediterranean Sea	1150	0.0013	3.23	0.97	This study

In this study, von Bertalanffy growth parameters of *S. canicula* were estimated as L_∞=56.70, K=0.20 year^{-1} and t_0=-1.60 year. Previously these parameters reported as L_∞=56.8 and K=0.53 for the Mediterranean by Zupanovic and Pauly (1961); L_∞=88.8 and K=0.13 by Rodriguez-Cabello *et al*. (1998) and L_∞=88.0 and K=0.20 for the Atlantic by Jennings *et al*. (1999); L_∞=82.7 and K=0.15 for Ireland by Henderson and Casey (2001); L_∞=87.12 and K=0.118 for international sea explorations by Ivory and Nolan (2005); L_∞=69.3 and K=0.21 by Rodriguez-Cabello *et al*. (2005) and L_∞=49.23 and K=0.57 for the Western Algeria by Bendiab *et al*. (2012). Our findings concerning the species of the Northeastern Mediterranean conforms with those reported above in general. The application of other growth parameters like K=0.15 and $L\infty$=82.7 cm (Henderson & Casey 2001) and K =0.20 and $L\infty$=88 cm (Jennings *et al.* 1999) for the same temperature, however, also gave relatively high values, M =0.29 and M = 0.35 respectively. A preliminary estimate of mortality based on the catch length distribution of commercial trawlers gives a Z=0.36 (Rodriguez-Cabello and Sanchez 2005). Natural mortality estimated using the empirical formula of Pauly (1980), which relates growth curve parameters and temperature to natural mortality, gave M = 0.36 using a K= 0.21 and L∞=69.3 cm and at mean temperature of 15 °C (Rodriguez-Cabello *et al*. 2005).

Instantaneous mortality coefficient and natural mortality values of *S. canicula* obtained from other areas are lower than those in our data. But the water temperatures in their areas are also lower than that in the Mediterranean. The differences may be caused by the higher water temperature in the Mediterranean and some other abiotic factors. In addition, Z values of *S. canicula* from other areas were also lower than that of *S. canicula* from the Mediterranean. The reason for this is thought to be the intensive trawling and the capture of smaller fish as an off-target in the northeastern Mediterranean. Empirical equations have been developed in order to estimate life-history parameters in fishes (Pauly 1980; Hoenig 1983) and in elasmobranchs (Cortes 2000; Frisk *et al*. 2001).

These parameters could be very helpful, for the management and conservation of some species.

In a situation using the mortality parameters, it the exploitation rate of *S. canicula* in Iskenderun Bay came out to be 0.56 (Figure 8). Considering that the maximum level of production was obtained when the exploitation or the utilization rate was E = 0.5 or in other words, when F= M, which indicates either under fishing pressure (Bingel 1987). It is suggested that the existing exploitation rate be reduced by 12% in order to maximize benefit from the stock.

In conclusion, since *S. canicula* grows slower and reach maturity in longer duration, its fisheries must be managed so that stock sustainability can be maintained in the northeastern Mediterranean. Selective fishing is recommended in order to reduce by-catching losses of the species especially during trawling operations.

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Kuzeydoğu Akdeniz'deki *Scyliorhinus canicula* (Linnaeus, 1758)'nın bazı populasyon parametreleri

Öz

Bu çalışmada Kuzeydoğu Akdeniz'in 155-400 m derinliklerinden Mart 2012-Mayıs 2014 tarihlerinde ticari tekneler ile 1150 küçük benekli kedi balığı (*Scyliorhinus canicula* L., 1758), (562 dişi, 588 erkek) toplandı. *Scyliorhinus canicula*'nın toplam boy ve ağırlıklarının 12.0 - 51.0 cm ve 4.13-396.0 g arasında değişiklik gösterdiği belirlenmiştir. Örneklerin dişi/erkek oranının 1:1.2 olduğu belirlenmiştir. *Scyliorhinus canicula*'nın boy frekans verileri; sonuşmaz uzunluk, büyüme katsayısı ve stok durumunu değerlendirmek için stoğa katılım gibi populasyon parametrelerini tahmin etmek için FISAT II programı kullanılarak analiz edilmiştir. von Bertalanffy büyüme denklemi parametreleri $L\infty$=56.70, k=0.20 yıl^{-1} ve t_0= -1.60 yıl olarak bulunmuştur. Boy-ağırlık ilişkileri $W=0.0013L^{3.239}$ (R^2=0.97) ve b değerinin 95% güven aralığı 3.209 - 3.271 olarak tahmin edilmiştir (t-test P<0.05). Büyümenin pozitif allometrik büyüme özellik sergilediği belirlenmiştir (b>3). Avlanma oranı dişilerde 34.94 cm ve erkeklerde 35.04 cm olarak hesaplandı. *S. canicula*'nın anlık toplam ölüm katsayısı Z = 1.06 yıl^{-1}, doğal ölüm katsayısı M = 0.47 yıl^{-1} (ortalama 21.9°C su sıcaklığında), avlanma ölüm katsayısı F = 0.59 yıl^{-1} ve işletme oranı E = 0.56 olarak bulunmuştur.

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