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Research Article

Some Parameters of the Population Biology of Spotted Flounder (*Citharus linguatula* Linnaeus, 1758) in Edremit Bay (North Aegean Sea)

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Abstract: A total of 1096 spotted flounder (*Citharus linguatula* Linnaeus, 1758) were caught in Edremit Bay from September 1998 to September 2000. Length-weight relationships, age, growth, mortality and sex ratio of the samples were investigated. Within the population of this species, most of the individuals in our samples ranged from 100 to 160 mm (69.63%), the minimum and maximum total lengths of the specimens being 69 and 222 mm, respectively. Positive allometric growth was observed for male, female and all fish. Age distribution of the samples was from I to IV. There was no significant difference between observed and calculated (von Bertalanffy and back calculation) average total lengths of the age groups ($P > 0.05$). The sex ratio (females:males) was 1:1.27. The total (Z), natural (M) and fishing mortality (F) rates, and the exploitation ratio (E) for all individuals were estimated respectively as $Z = 0.60$, $M = 0.75$, $F = 0.15$ and $E = 0.25$. This shows that the spotted flounder stock of Edremit Bay is being exploited at a lower than optimal level.

Key Words: *Citharus linguatula*, Edremit Bay, age, growth, mortality, sex ratio

Edremit Körfezi (Kuzey Ege Denizi)'ndeki Pisi Balığı (*Citharus linguatula* Linnaeus, 1758)'nın Populasyon Biyolojisi Üzerine Bazı Parametreler

Özet: Edremit Körfezi'nden Eylül 1998-2000 yılları arasında toplam 1096 adet pisi balığı (*Citharus linguatula* Linnaeus, 1758) yakalandı. Örneklerin boy-ağırlık ilişkileri, yaş, büyüme, mortalite ve eşey oranı araştırıldı. Bu türün populasyonundan elde edilen bireylerin çoğu 100-160 mm (% 69,63) arasında dağılım gösterip türlerin en az ve en yüksek total boyları sırasıyla 69 ve 222 mm' dir. Erkek, dişi ve tüm bireyler için pozitif allometri gözlenmiştir. Bireylerin yaş dağılımı I-IV arasında bulunmuştur. Tüm yaş gruplarında gözlenen ve hesaplanan (von Bertalnffy ve geri hesaplama) ortalama total boylar arasında önem farkı yoktur ($P > 0,05$). Eşey oranı (dişi:erkek) 1:1,27 dir. Toplam (Z), doğal (M) ve balıkçılıktan gelen mortalite (F) oranları, sömürü oranı (E) tüm bireyler için sırasıyla $Z = 0,60$, $M = 0,75$, $F = 0,15$ ve $E = 0,25$ olarak hesaplanmıştır. Bu Edremit Körfezi'ndeki pisi balığı stoğunun optimal sömürüden daha düşük düzeyde sömürüldüğünü göstermektedir.

Anahtar Sözcükler: *Citharus linguatula*, Edremit Körfezi, yaş, büyüme, mortalite, eşey oranı

Introduction

Citharus linguatula, a flat and demersal fish that belongs to the family Citharidae (Linnaeus, 1758), is distributed in the Mediterranean and East Atlantic (1). *C. linguatula* is most likely to be found at 10 to 100 m depth although it may be seen in shallow waters to 200 m depth (2).

C. linguatula is distributed in the Mediterranean, Aegean and Marmara seas in the territorial waters of Turkey (3). Thirty percent of the total sole and plaice production of Turkey comes from the Aegean Sea (4). This species is caught very abundantly during the fishing of other economically important demersal fish species by trawling in Edremit Bay.

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There are few studies on the population biology of *C. linguatula* in the Aegean Sea. Vassilopoulou and Papaconstantinou (5) reported some information on the age, growth and mortality of *C. linguatula* individuals in the Aegean Sea. Additionally, valuable information on the biological parameters and mortality of *C. linguatula* species was reported by Stergiou et al. (6).

The aim of this study was to determine some parameters (age, growth, mortality and sex ratio) of the population biology of *C. linguatula,* which is harvested in significant amounts in Edremit Bay, in order to compare the population characteristics of this species in other seas. The data on these parameters are expected to be helpful in fisheries management in Edremit Bay.

Materials and Methods

Edremit Bay is located between 39°17"N and 39°34"N latitudes and 26°57"E and 26°34"E longitudes. It measures 34.5 km from east to west and 25.5 km from north to south. The bottom structure is sandy-muddy in general.

One thousand ninety-six individuals caught by commercial trawlers in Edremit Bay between September 1998 and September 2000 were investigated. Trawl surveys were performed in 30 to 80 m depth in waters with sandy-muddy bottoms. The sex ratio was determined by investigating the gonads of the individuals and, additionally, total and standard length (TL and SL, respectively) and total weight (TW) were measured with 1 mm and 0.01 g precision, respectively.

The otoliths of 279 individuals selected randomly to represent all length groups were removed and then stored in dry conditions inside envelopes. The otoliths were washed and cleaned several times in NaOH solutions 24 h later and then the age of the otoliths was determined using a stereomicroscope with a micrometer attached to the eyepiece (7). Otoliths that could not be clearly observed were checked following the process of thinning by sandpaper. Otoliths on the right - hand side were selected for the measurements as they were easier to observe.

The relationship between length and weight was established as $W = a L^b$, where W is body weight (g), L is total length (cm), and a and b are coefficients (8).

Lengths at annulus formation were back-calculated using the TL-R regressions according to the Fraser-Lee method (in 9); $L_a = d + (L_c - d) O_c^{-1} O_a$, with L_c and O_c being the fish length and otolith size at capture, respectively, d the intercept of the regression, and O_a the otolith size at a previous age (a).

Total length and width (the long axis and the short axis) of the otoliths were measured by ocularmicrometer; additionally, the radius of the nucleus was measured and length values for the annual age rings (transparent and non-transparent zones) were noted (10).

The growth model was determined by $Lt = L\infty [1 - \exp^{-K(t-t_0)}]$ (11), where *Lt* is the length at age t, $L\infty$ is the maximum asymptotical length, K is the growth coefficient, and t_0 is the theoretical age of the fish prior to hatching from the egg.

Total mortality (Z) was estimated from the method of survivor rate (12), $S_{(t)} = N_{(t+1)}/N_{(t)}$ where S is the survivor rate, $N_{(t+1)}$ is the number of fish belonging to the age group 1 year later, and N(t) is the number of fish belonging to the age group being investigated. There is a relationship between S and Z of $S = e^{-Z(t)}$ and $Z\% = 100 * (1 - e^{-Z}t)$. The natural mortality rate (M) was estimated from the following equation (13): $M = 3/T_{max}$, where T_{max} is the age of the oldest fish sampled. Following estimation of Z and M, the fishing mortality rate (F) was estimated from F = Z - M, and the exploitation ratio (E) from E = F / Z.

Student's t test was used to test the significance of the difference between the length and weight of males and females, and chi-square test was used to determine the significance of the male to female ratio. Since the difference between the length and weight of males and the females was not significant, all individuals were evaluated as a whole.

Results

Length, Weight, Age and Sex Distribution

Minimum and maximum weight and total length values of females, males and all fish were 1.6-74.7 g and 69-214 mm, 2.12-84.58 g and 69-222 mm and 1.6-84.6 g and 69-222 mm, respectively (Table 1). Length and weight values were statistically nonsignificant in relation to sex in the *C. linguatula* population ($P > 0.05$).

Table 1. In males, females and all fish; (A) total and standard length (mm), weight (g) values (SE: Standard error).

	Female		Male		t test	All fish	
	Min-Max	Mean ± SE	Min-Max	Mean ± SE		Min-Max	Mean ± SE
W	1.6-74.69	20.95 ± 0.66	2.12-84.58	22.79 ± 0.63	>0.05	1.6-84.58	20.95 ± 0.44
SL	58-185	116.7 ± 0.11	38-186	121.8 ± 0.11	>0.05	38-186	119.4 ± 0.08
TL	69-214	136.7 ± 0.145	69-222	144.5 ± 0.13	>0.05	69-222	140.9 ± 0.10

The relationship between total length (TL) and standard length (SL) can be described by the regression equation SL = 0.295 + 0.8273 TL (r = 0.99).

Within the population of this species, most of the individuals in our samples ranged from 100 to 160 mm (69.63%), with the minimum and maximum total lengths being 69 mm and 222 mm, respectively.

The age distribution of individuals belonging to the *C. linguatula* population was I to IV. Most individuals were obtained from the group of II - year-old fish followed by the I – year - old group (Table 2).

Table 2. Age-length key (%).

Length group (mm)	N	Age			
		I	II	III	IV
101-110	12	100			
111-120	51	70.6	29.4		
121-130	24	50	50		
131-140	24	50	50		
141-150	12		100		
151-160	12	50	50		
161-170	21	28.6	71.4		
171-180	15	20	80		
181-190	18		83.3	16.7	
191-200	27		88.9	11.1	
201-210	33		27.3	36.4	36.4
211-220	18			50	50
221-230	12				100
	MTL	126.31	162.41	203.56	215.18
	SE	1.94	2.48	1.56	1.29
	N	87	132	27	33

MTL = Mean total length, S.E. = Standard error, N = Number of specimens.

Of the fish examined, 614 were male and 482 female. The overall ratio of females to males was 1:1.27 and chi-square analysis showed this difference to be significant ($\chi^2 = 63.18$, $P < 0.05$).

Growth

Positive allometric growth was observed for male, female and all fish. Length-weight regression parameters for males, females and all individuals are presented in Table 3. No significant difference in the allometric coefficient was found between males and females (t-test, $t < t_{0.05,\ n > 200} = 1.65$). Weight growth is faster than length growth. From linear regression analysis for otolith-fish length (OL-TL) the relationship of both sexes combined was estimated as follows: OL = 0.0221 TL + 1.3774 (r = 0.92).

Table 3. In males, females and all fish; parameters of the length-weight relationship ($W = aTL^b$) (a: Intercept, b: Slope, SE: Standard error, N: Number of specimens, r^2: Correlation coefficient).

	N	a	b	SE (b)	r^2	t test
Males	615	0.004	3.2126	4.914	0.979	0.043
Females	481	0.003	3.2852	3.745	0.99	0.076
All fish	1096	0.003	3.2405	4.436	0.981	0.054

(t test, $t < t_{0.05,n>200} = 1.65$)

Parameters of the von Bertalanffy growth equation were calculated for all individuals. According to these calculations, $L\infty$ was 253.4 mm, k was 0.25 years and t_0 was 1.68. For all fish, the growth model was $Lt = 25.34\ [1 - e^{-0.25\ (t+1.68)}]$. Using the allometric relationship between otolith length and total length, one can determine the length of a wild-caught fish from its otolith. In this study of *C. linguatula* specimens from

Edremit Bay, the relationship between total length and the otolith measurement was linear but not directly proportional, and the line crossed the ordinate at a positive length. Thus, according to the Fraser-Lee equation [$L_a = d + (L_c - d)\ O_c^{-1}O_a$], the back-calculated lengths at various ages are given below (Table 4).

Table 4. Average total lengths (mm) in each age group determined by back calculation.

AGE	L1	L2	L3	L4
IV	101.62	151.91	192.15	205.60
III	102.63	153.27	176.46	
II	115.02	137.24		
I	102.26			
MBTL	108.3	142.0	185.1	205.6
SE	2.09	2.30	2.37	1.11
N	87	132	27	33
An. Incr.	108.25	33.76	43.07	20.51
An. Incr %	52.65	16.42	20.95	9.98

MBTL = Mean back-calculated total length, S.E. = Standard error, N = Number of specimens, An. Incr. = Annual increment.

Theoretical length values were compared with the natural length values for each age group calculated according to the equations obtained with both methods (Table 5).

No statistically significant difference was found between the average length of the individuals caught in nature according to each age group and the theoretical average length calculated by the von Bertalanffy equation and back - calculations ($P > 0.05$) (Table 6).

Mortality

The total (Z), natural (M) and fishing mortality (F) rates, and the exploitation ratio (E) for all individuals were estimated respectively as $Z = 0.60$, $M = 0.75$, $F = 0.15$ and $E = 0.25$.

Discussion

A high correlation was found between total length and standard length. This result coincides with a similar study by Vassilopoulou and Papaconstantinou (5).

Positive allometric growth was observed for male, female and all fish. Similar results have been reported from other areas in the Aegean Sea, Egyptian Mediterranean waters and eastern Adriatic (5,14-16). In contrast with the study by Vassilopoulou and Papaconstantinou (5), no significant difference in the allometric coefficient was found between males and females in this research (Table 6).

The theoretical maximal length value ($L\infty = 253.4$ mm) was close to the size of the largest (222 mm) fish examined and the growth coefficient value ($K = 0.25$ year^{-1}) indicated that growth was similar to the results given by Vassilopoulou and Papaconstantinou (5) ($L\infty =$ 229-259 mm, $K = 0.25$-0.29 year^{-1}).

Table 5. Mean of total length values (mm) according to age groups.

Age	N	Group 1	SE	t test	Group 2	t test	Group 3
I	87	126	41.8	0.42	108.3	0.05	123.9
II	132	162	37.4	0.54	142	0.25	152.6
III	27	204	41.8	0.45	185.1	0.70	174.9
IV	33	215	19.8	0.47	205.6	1.15	192.3

(t test, $t < t_{0.05,n>200} = 1.97$)

Group 1: The means of length of specimens caught in nature;
Group 2: The means of length from back calculation;
Group 3: The means of length calculated theoretically using the von Bertalanffy equation; SE: Standard error from group 1.

Table 6. Minimal, maximal and average length and weight values and values for the length-weight relationship in the *C. linguatula* population.

Author	Weight (g)	Length (mm)	Length-weight relationship		
	Min-Max	Min-Max	a	b	r
Bingel 1987 (17)	-	62.2-170	-	-	-
Vassilopoulou and Papaconstantinou 1994 (5)	-	60-240 (TL)	0.000036	3.125	0.99
Redon et al. 1994 (18)	-	60-230	-	-	-
Dulcic and Kraljevic 1996 (15)	16-84	131-206	0.000053	3.237	0.910
Present study	1.6-84.58	69-222 (TL)	0.0033	3.2405	0.981

a: Intercept, b: Slope, r: Correlation coefficient.

We found that the spotted flounder ranged up to age-group IV in Edremit Bay. However, Vassilopoulou and Papaconstantinou (5), who studied the spotted flounder of the Aegean Sea, reported the maximum age as VII.

These results are related to regional differences in environmental factors and especially the differences in sampling depth between the studies (5,15,17,18) (Table 6).

The high correlation found between total length and otolith radius demonstrates the validity of using otoliths for estimating the age and past growth history of the spotted flounder.

The exploitation ratio for all fish (E = 0.25) in the present study is low. According to Gulland (19), the optimal exploitation level is E = 0.50. This shows that the stock of the spotted flounder in Edremit Bay is being exploited at a lower than optimal level.

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