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Research article

Growth and reproduction properties of the poor cod, *Trisopterus capelanus* (Lacepède, 1800) (Gadidae) in the Edremit Bay, Northern Aegean Sea, Turkey

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Abstract: Age, growth, gonadosomatic index and condition factor of poor cod, *Trisopterus capelanus* were evaluated from 593 specimens collected in Edremit Bay, the northern Aegean Sea between the years of March 2015 and February 2016 by the hauls of trawls. Total length ranged between 10.7-19.8 cm and 9.6-17.0 cm while weight varied between 9.34-95.59 g. and 8.13-51.45 g. in females and males. The male and female ratio was 1:0.42 (M:F) in the favor of males. The von Bertalanffy growth equations (in length) were found as L_t= 23.5 ($1-e^{-0.52(t+0.50)}$) for all individuals. Length-weight relationships were found to be $W=0.0089L^{3.0665}$ (R^2=0.9299), $W=0.0112\times L^{2.9655}$ (R^2=0.9125), and $W=0.0087L^{3.0692}$ (R^2=0.9347) for females, males and combined sexes, respectively. As the determination b values are not statistically significant from 3 (t test, p>0.05), isometric growths were observed for all samples. The condition of the fish increased during autumn. A long spawning season (about 4-5 months) in late winter-early spring occured in the population. Analysis of the diet composition showed that poor cod is carnivourus and the food composition of *T. capelanus* consists of mostly crustaceans as *Alpheus glaber* and *Liocarcinus* sp. Poor cod has an economic value for Turkish Seas and it is also important in the view of biodiversity.

Keywords: *Trisopterus capelanus*, Edremit Bay, growth, condition, gonadosomatic index.

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Introduction

Poor cod, *Trisopterus capelanus* (Lacepède, 1800) is a gadoid fish, which inhabits the Mediterranean Sea (Hureau, 1986). It is common in the Mediterranean Sea on the sandy-muddy bottoms between depths of 40 and 120 m (Choen et al.1990). It spawns in the winter-spring seasons (Jardas, 1996). The poor cod is an opportunistic predator whose diet consist various bottom-living prey groups, with wide range of sizes and morphologies (Šantić et al. 2009). However, there have been few investigations on the biology of the species in the Mediterranean Sea. Planas and Vives (1952) and Vives and Suau (1956) described various aspects of its life history from the Spain coasts. While Froglia et al. (1981) and Tangerini and Arneri (1984) provided some information on growth, distribution and spawning of *T. capelanus* of the Adriatic Sea, and recently, Gianetti and Gramitto (1988) and Santic et al. (2018) have estimated its age and growth by using otoliths. Šantić et al. (2018) also gave some morphometric and meristic characters of poor cod from the the Adriatic Sea

Trisopterus capelanus is one of the most abundant endemic species in the Mediterranean. It is considered one of the main target species of commercial trawl fisheries, in Edremit Bay (Ünlüoğlu, 2015). Despite its importance as by-catch species in this region, there is a lack of biological information available for this species and there are no stock assessments. The present study deals with growth and reproduction of *T. capelanus.* Published informations on the poor cod in Turkish Seas are limited to notes on geographical distribution (Akşiray, 1987; Torcu & Aka, 2000; Eryılmaz, 2001), its growth (Gökçe

& Metin, 2004; Ünlüoğlu, 2015). The clarification of some biological parameters of such an important target species by catch is essential for management in marine systems.

The present study deals the determinations of the biological characteristics of *T. capelanus* stock such as growth rates, length distributions, reproduction as well as mortalities in Edremit Bay, the northern Aegean Sea.

Material and Methods

The Edremit Bay is situated along the coasts of Çanakkale and Balıkesir between Küçükkuyu and Ayvalık, a place where two currents meet; upwelling in the bay also makes it rich in plankton. In addition, because the coastal bottom is suitable for trawl fishing, the area is fed by nutrient-rich waters from erosion through the proximity of the bay to the Black Sea, where there is a rich bottom fish fauna. With these advantages, Edremit Bay has high seafood potential, especially fish (Toğulga, 1997).

The sampling was carried out by the commercial trawl vessel, Salih Reis at a depth of 40 m between Maden Island and Kücükkuyu, Edremit Bay (39°27038″N; 26°32031″E) from March 2015 to February 2016, except for between May and August due to fishing ban. Haul duration was about 15 min and boat speed 2 mph. The trawl was equipped with a 44 mm stretched mesh size at the cod-end. The sample was identified at species level according to FishBase (Hureau, 1987; Nelson, 2006; Delling et al., 2011). Total lengths (TL) was measured with a dial caliper of 0.05 mm accuracy, and the weight (0.01 g) measured; the sex of each specimen were determined macroscopically and the overall sex ratio was determined. Deviations from 1:1 hypothesis were tested statistically by chisquared analyses (Sokal and Rohlf, 1981).

Sagittal otoliths were used for age determination. Otoliths were removed and then, soaked in 5% HCL and 3% NaOH solutions, respectively, and washed in distilled water and subsequently dried. The otoliths, placed in petri dish filled with glycerine, were read using a stereoscopic zoom microscope under reflected light against a black background. Opaque and transparent zones were counted; one opaque zone plus one transparent zone were assumed to be one year (Chugunova, 1963; Lagler, 1966). Each individual structure was independently examined once by two readers. Growth was examined according to length and weight.

Length-at-age data were used to estimate the parameters of the Von Bertalanffy (1938) growth function VBGF: $L_t = L_\infty[1-e^{-k(t-t_0)}]$, where L_T is the total length of the fish at time t, $L\infty$ is the ultimate length an average fish could achieve, k is the growth constant which determines how fast the fish approach $L\infty$ and t_0 is the hypothetical time at which the length of the fish is zero (Sparre and Venema, 1992). Phi'-prime (Φ') index was calculated to compare the growth performance of the poor cod as: $\Phi = \text{Log}(k)\ 2\ \text{Log}(L_\infty)$ where k and $L\infty$ are parameters of VBGF (Munro, 1984). The relationships between total length TL and total weight W were calculated for males and females separately using the allometric model: $W=a*L^b$, (Avşar, 2016), where W is fish total body mass in grams, TL is total length in cm, a is a constant and b the allometric coefficient.

The spawning period of *T. capelanus* was determined by analyzing the monthly evolution of the gonado-somatic index (GSI), according to the expression: GSI=[Gonad weight/(Body weight-gonad weight)*100] (Avşar, 2016). During the reproductive cycle, physiological condition was determined monthly from the hepatosomatic index (HSI%) and the condition factor (CF).

Condition factor (CF) was calculated as $CF=(W/L^3)*100$ for each sex to assess the maturity, condition of specimens and an overall measurement of being strong and healthy of the fish (Avşar, 2016). Hepatosomatic index [(HSI=(liver weight/gutted weight)×100)]: this estimates the relative size of the liver to body weight (Garcia-Diaz et al., 2006).

The total instantaneous mortality (Z) was calculated by the linearized catch curve using fish captured with multimesh gillnet. The natural mortality coefficient (M) was estimated from tentative Pauly's formula (Pauly and Munro, 1984): Log (M)=-0.0066-0.279log(L∞)+0.6543log(K)+0.4634 log (T), where T is the water average annual temperature of fish habitat. In this study, T was 12 °C. Fishing mortality coefficient (F) was calculated using the below formula: Z = M + F, exploitation rate was calculated using the formula: E= F/F+M (Sparre & Venema, 1992)

Results

Length and weight frequency distribution

The total lengths varied in 10.7-19.8 cm and 9.6-17.0 cm while the weights ranged from 9.34 to 95.59 g. and 8.13 to 51.45 g. in females and males, respectively.

Age composition and sex ratio

As to age and sex distribution data age groups of captured fish ranged between I and III, the first year class was dominant and it can be expressed that the poor cod population consisted of young individuals. Because of selectivity of the nets, the 0 age group was not represented in the sampling. The male and female ratio was 1:0.42 (M:F) in the favor of males. and differences between sexes according to age were statistically significant (Chi-square test, P<0.05).

Growth

The age-weight relationship in all individuals was estimated as Lt= 23.5(1-$e^{-0.52(t+0.50)}$), for all individuals with the growth performance, 3.19.

Length–weight relationship

Length-weight relationship was calculated by using the data of 593 *T. capelanus* specimens. These were plotted in Table 1.

Table 1. LWR values for *Trisopterus capelanus* population in Edremit Bay

Sex	N	a	b	R^2	Growth Type
Female	174	0.0089	3.0665	0.9299	Isometric
Male	419	0.0112	2.9655	0.9125	Isometric
Combined	593	0.0087	3.0692	0.9347	Isometric

Condition factor (CF%)

Monthly seasonal conditions exhibited a similar pattern for all individuals, showing a peak in March (Fig. 1).

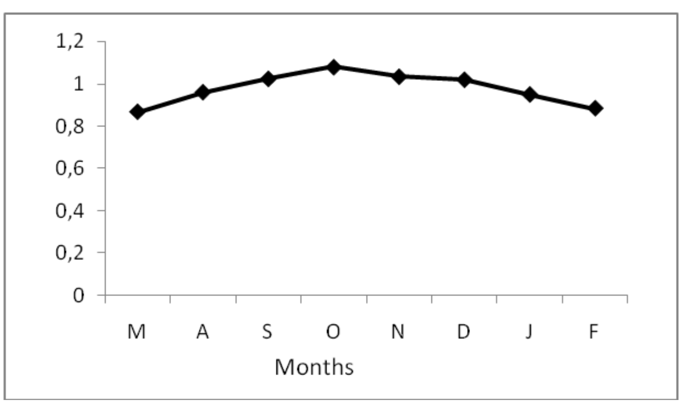

Figure 1. Monthly variations in CF of *Trisopterus capelanus* population in Edremit Bay between the years 2015-2016.

Gonad development and spawning period (GSI%)

Gonad development was followed using the GSI. Monthly changes are plotted in Fig. 2. Spawning raised up from November with a peak in February.

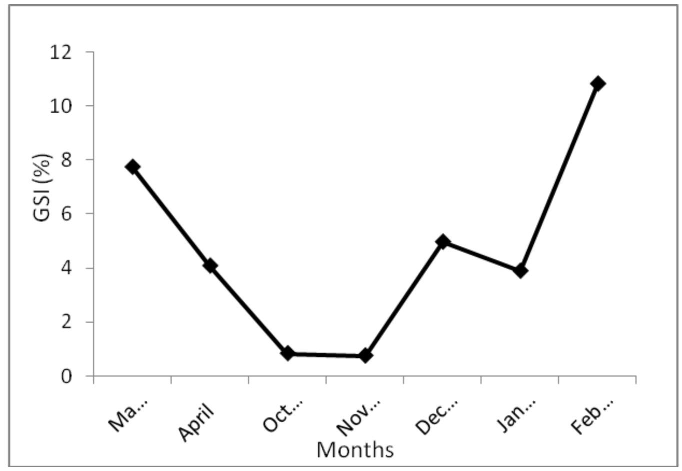

Figure 2. Monthly variations in GSI% of females of *Trisopterus capelanus* population in Edremit Bay between the years 2015-2016.

Hepatosomatic index (HSI%)

In general, monthly HSI values showed a peak in April in all population (Fig. 3).

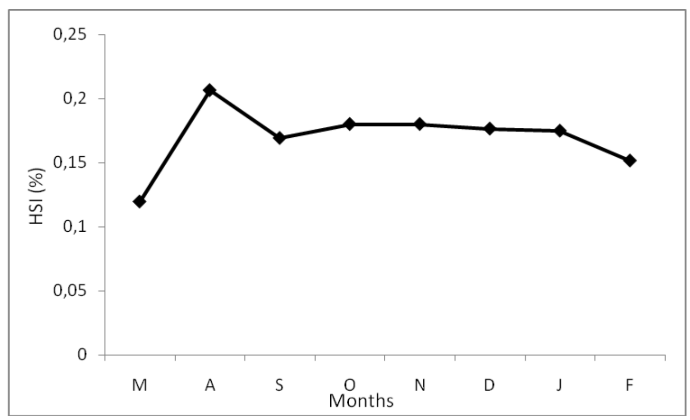

Figure 3. The values of monthly HSI of all *Trisopterus capelanus* population from Edremit Bay between the years 2015-2016.

Mortality parameters

The values of mean Z, M, and F were calculated as Z=1.84 $year^{-1}$, M=0.36 year-1, F=1.49 $year^{-1}$ in the 2015-2016 fishing season, respectively. The exploitation rate (E) was 0.8.

Discussion

Of 593 specimens measured, TL of males ranging from 8.1.2 to 51.5. cm; the range (9.3–95.6 cm) for females was higher than for males (Table 2). However, the difference between TL means of female and male fish for all yearclasses was not significant ($P > 0.05$, t-test) (Table 2). These variations may be due to different stages in ontogenetic development, as well as differences in condition, length, age, sex and gonadal development (Ricker, 1975). Geographic location and some environmental conditions such as temperature, organic matter, quality of food, time of capture, stomach fullness, disease, parasitic loads (Bagenal & Tesch, 1978), temperature, organic matter, quality of food and the water system in which the fish live (Wooton, 1998; Treer et al., 1999) can also affect weight at-age estimates.

It was found that 29.35% of the *T. capelanus* population in Edremit Bay consisted of females and 70.66% of males. This fact can be explained that males inhabited in shallower waters than females (Biagi et al., 1993). The sex ratio was 1:0.42 (female) to 1 (male) and significantly different from 1:1 (Chi-square test, $P<0.05$) as similiar as findings in the northern Aegean Sea by Ünlüoğlu (2015). Papaconstantinou (1990) mentioned the overall sex ratio showed a favour of females. Nikolsky (1980) indicated different sexual dispersions of the same species in different populations. It is well known that the sex ratio in most species is close to one, but it may vary from species to species, differing from one population to another of same species and may vary year to year in the same population. According to Papaconstantinou (1990), the sex ratio of the species varies considerably as a result of differential behaviour and mortality rates between the sexes. Maximum age group was found as III. As the most specimens were in I age group, it can be expressed that the poor cod population consisted of young individuals (Table 2). In relevant literature, age distributions were reported to be I-V, VI-VIII, O-IV, and I-VI in Greek waters by Papaconstantinou (1990), Strait of Sicily and Aegean Sea by Ragonese and Bianchini (1998) and in Aegean Sea by Metin et al. (2008), respectively, as different from our findings in Edremit Bay. These differences in the age distributions of the populations may be due to gill net selectivity, fishing activity, feeding habits and the ecological characteristics of the lakes and reservoirs (Nikolsky, 1980; Wooton, 1992). The von Bertalanffy growth equations (age-length relationships) calculated with mean lengths at different ages were found as $L_t=23.5\ (1-e^{-0.52(t+0.50)})$, for all individuals. Similarly, high growths of poor cod (K=0.56, 0.6) were calculated by Gianitti and Giramitto (1988) and Righini et al. (1995) in Adriatic Sea and Tiran Sea. On the contrary, in the Middle Aegean Sea, Metin et al. (2008) reported a slower growth coefficient (K=0.26). Such differences in the growth rates can result partly from the different techniques used but more likely reflect slight environmental differences (temperature, food availability, hydrographic nature). According to Sparre and Venema (1992), ∅' is the best index of overall growth performance, in the sense that it has minimum variance. For poor cod from Edremit Bay, the ∅' value of combined sexes was found as 3.19. The growth performance index of the poor cod was found to be 2.31 for the total population. This value was higher than the calculated growth performances in English Chanel and Adriatic Sea (Table 2). These differences in growth performance between the marine systems can be attributed to the difference in size of the largest individuals sampled and a different calculated method.

Determination of age and growth rate is very important in ichthyologic investigations, as fish growth is one of the main factors that determines stock conditions. Parameters of length-weight relationships (LWRs) have several applications in the field of fish biology, physiology, ecology and fishery assessment. Furthermore, LWRs are fundamental for the estimation of weight-at-age (Petrakis and Stergiou, 1995). The length-weight relationships were pooled for females (n=174, a=0.0089; b=3.0665, $R^{2=}0.9299$), males (n=419, a=0.0112; b=2.9655, $R^2=0.9125$) and combined sexes (n=593, a=0.0087; b=3.0692, $R^2=0.9347$) in Table 1 and 2. The b values in female, male, and all individuals indicated an isometric growth (Table 1 and 2). For the same species, the b value was reported to be 2.97-3.01 in Adriatic by Santic (2015). The *b* value in length-weight relationship equation is an indicator of the body shape of the fish, affected directly by the habitat in which the fish lives (Nikolsky, 1980). The values b are often 3.0 and generally between 2.5 and 3.5. As a fish grows, changes in weight and relatively greater than changes in length, due to approximately cubic relationhip between fish length and weight. The values *b* in fish differ according to species, sex, age, seasons, feeding, disease, and parasite loads (Bagenal & Tesch, 1978).

For the condition factor in poor cod population, the minimum mean CF was in March in all specimen in Figure 2. The gonad development was followed using the GSI% and monthly changes are plotted in Figure 3. Spawning occured between November and March, showing a peak in February. During spring and early of summer, an obviously rapid growth of gonads occured untill the next spawning. Metin et al. (2008) found that values of gonadosomatic index high between January and April as similar from our findings except for those reported by Ünlüoğlu (2015). Because the ecological and climatical conditions are different, the starting and finishing time of reproduction may include different months (Nikolsky, 1980). The hepatosomatic index is an indicator of feeding activity of fish (Tyler & Dunn, 1976). The hepatosomatic index shows an allocation of energy to the liver during every period except reproduction, when part of the energy is used for gonad maturation (Nunes, 2001). Since total length and weight are included in the calculation of GSI and HSI, they present an auto–corelation (Çek et al., 2001). The hepatosomatic index (HSI) showed higher value in April, then decreased to the lowest values in February-March, followed by an increase in the subsequent months (Fig. 4). In this study, the values of hepatosomatic index are found to be following a different trend according to values of gonadosomatic index. This is not a harmony with the different species studied by Htun-Hun (1978), Delahunty and De Vlaming (1980), Avaji and Hanyu (1987), Asahina et al. (1990), Çek et al. (2001), Kingdom and Allison (2011). This may be of differences in length measurements.

Table 2. The age structure, parameters of length–weight relationship (a and b), growth (L_∞, k, t_0) and CF of *Trisopterus capelanus* population in this and previous studies (– indicates absence of data)

Length range (cm)	Age	N	a	b	R^2	L_∞	k	t_0	Φ'	Area	References
						20.0	0.42		2.23	English Channel	Menon (1950)
						22.0	0.39		2.28	Vinaroz Islan.	Planes and Vives (1952)
3.0-30.0	-		0.0059	3.22	-	-	-	-		Adriatic	Froglia and Zoppini (1981)
		-	0.005	3.27	-					Adriactic	Tangerini and Alneri (1984)
		5795				36.0				North Evvoikos G.	Papaconstantinou et al. (1987)
		24466				28.0				Ionian Sea	Papaconstantinou et al.(1987)
5.3-31.0	-		0.0059	3.22	-	23.27	0.32	-1.62	2.24	Ionian Sea	Politou and Papaconstantinou (1990)
-	I-V	4519	0.0059	3.07	0.83	32.27	0.18	-1.83	-	Greek waters	Politou and Papaconstantinou (1991)
-	-	-	0.0083	3.05	-	-	-	-		Tiran Sea	Biagi et al. (1991)
16.0-41.0			0.0059	3.26		23.8	0.56	-1.867	1.35	Adriatic	Gianitti and Giramitto (1993)
						28.5	0.6			Tiran Sea	Righini et al.(1995)
4.7-23.7						22.23	0.45	0.679-	2.36	Strait of Sicily	Ragonese and Bianchini (1998)
						20.0	0.51		2.31	North Sea	Jennings et al. (1999)
			0.005	3.26						Tiran Sea	Relini et al. (1999)
			0.059	3.22		24.82				Adriatic Sea	Relini et al. (1999)
						23.37	0.49	0.627		Edremit Bay	Ünlüoglu (2015)
	1-V					28.1	0.26	-1.52	2.31	Aegean Sea	Metin et al. (2008)
9.2-25.5	1-6	1200				28.78	0.19	1.34		Adriatic Sea	Šantić (2015)
8.4-9.5										Adriatic Sea	Šantić et al. (2018)
9.6-19.8-	I-III	593	0.0087	3.069	0.93	23.5	0.52	-0.5	3.19	Edremit Bay	Present study

It was found that the basic food items consisted of crustaceans as *Alpheus glaber* and *Liocarcinus* sp. in stomach of poor cod individuals. The fact that *T. capelanus* specimens have well-developed barbels and long pelvic finrays has pointed out that its feeding is related to benthos. Mattson (1990) mentioned that jaw structure of poor cod is suitable for grasping and rapid ingestion of benthic organisms and as *A. graber* is seen in the holes at night, is an easy prey for he fish. Politou and Papaconstantinou (1994) reported that big fishes will feed on a various of foods. Dulčić and Dulčić (2004) and Biagi et al. (1993) reported crustaceans such as *A. glaber* in the stomach contents of poor cod from North Tiran Sea as well as in Greece waters, Adriatic and western Mediterranean reported by Gramitto (1999) and Morte et al. (2001).

Mortality and exploitation rates are important for understanding the the future of fish stocks (Pauly, 1980b). The exploitation rate of the poor cod has been estimated up to 0.80 which shows the undesirable exploitation amount (E< 0.5). In 2015-2016, overall mortality, rate the natural mortality and fishing mortality of the gibelio have been estimated up 1.84 $year^{-1}$, $0.36 yr^{-1}$, $1.49\ yr^{-1}$, respectively. It was found that natural mortality was higher than fishing mortality, because of insufficient fishing. the E rate is an index of fishing levels, and it should be E=0.50 for maximum sustainable fishing (Sparre & Venema, 1992). Pauly (1980b) suggested that, a fish stock is sustainable with fishing at a level of fishing mortality that generates E=0.5, where F=M, but in the present study F>M. This shows that the stock of the poor cod in the Edremit Bay is being exploited higher than the optimal level.

Conclusions

Edremit Bay, in the northern Aegean Sea, is a place where two currents meet and it is rich in plankton because of upwelling. In addition, the area is fed by waters rich in nutrient from erosion through the Sea of Marmara and the Black Sea. With these facilities, Edremit Bay has a high potential for sea food, especially fish. Since the Bay of Edremit is also known to be a nursery for many species of both pelagic and demersal species (Toğulga, 1977; Bilecik, 1989), it is important to point out that closure of Edremit Bay for trawl fisheries 18 years ago (Anonymus, 1995; Çelik & Torcu, 2000), has positively affected the poor cod population. The fact that purse seine fishery has not been forbidden in Edremit Bay may also lead to the presence of young poor cods in the catch, which are chosen as target species.

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Ethical Approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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The authors don't declare any fund.

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

HB wrote the thesis under the supervision of HTK, HTK wrote the manuscript, HTK and ZE drew the tables, all of authors read the final of the manuscript and confirmed.

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