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Abstract: A total of 1527 of poor cod (*Trisopterus minutus* Linn., 1758) were collected by trawl hauls between April 2001 and March 2002 from İzmir Bay (central Aegean Sea). The size of the fish (total length) ranged from 10.6 cm (minimum, September) and 24.8 cm (April). The population was composed of 53% males, 41% females, and 6% immature individuals, with a female to male ratio of 1:1.3. The age composition of the samples was from I to V. The von Bertalanffy growth parameters were L_∞ = 28.1 cm, W_∞ = 254.0 g, K = 0.26 y^{-1}, and t_0 = –1.52 y. The length at first sexual maturity was 13.3 cm in females and 12.5 cm in males. Spawning season begins in December and reaches its maximum level in January while continuing April. Fecundity ranged from 1236 to 21,463 eggs/female and showed significant correlation with fish length and weight. The total (Z), natural (M), and fishing mortality (F) rates, and the exploitation ratio (E) for all individuals were estimated respectively as Z = 0.82, M = 0.38, F = 0.44, and E = 0.57 y^{-1}. This shows that the poor cod smaller than 14 cm must not be harvested and fishing should be prohibited from January to April and that the poor cod stock in the central Aegan Sea is being exploited at a slightly higher than the optimal level.

Key Words: *Trisopterus minutus*, age, growth, mortality, reproduction, sexual maturity length, central Aegean Sea

Orta Ege Denizi Tavuk Balığı (*Trisopterus minutus* Linn., 1758)'nın Büyüme, Ölüm ve Üreme Özellikleri

Özet: Trol çekimleri ile 1.527 adet tavuk balığı (*Trisopterus minutus* Linn., 1758) Nisan 2001 ile Mart 2002 tarihleri arasında İzmir Körfezi'nden (Orta Ege Denizi) örneklenmiştir. Örneklenen bireylerin total boylarının 10,6 cm (minimum, Eylül) ile 24,8 cm (Nisan) arasında dağılım gösterdiği gözlenmiştir. Bireylerin %53'ünün erkek, %41'inin dişi ve %6'sının eşeysel olgunluğa ulaşmamış bireylerden oluştuğu tespit edilmiştir. Stokdaki dişi:erkek oranının 1:1,3 olduğu ve bireylerin I-V yaşları arasındaki dağılım gösterdiği gözlenmiştir. Von Bertalanffy büyüme parametreleri; L_∞ = 28,1 cm, W_∞ = 254,0 gr, K = 0,26 $yıl^{-1}$ ve t_0 = –1,52 yıl olarak hesaplanmıştır. Dişilerde ilk üreme boyunun 13,3 cm, erkeklerde ise bu boyun 12,5 cm olduğu bulunmuştur. Yumurtlamanın Aralık ayında başladığı, Ocak ayında maksimum seviyeye ulaştığı ve Nisan ayına kadar sürdüğü gözlenmiştir. Yumurta verimliliğinin 1,236 ile 21,463 yumurta/dişi arasında olduğu ve bu verimin balık boyu ve ağırlığı ile ilişkili olduğu tespit edilmiştir. Stoktaki toplam (Z), doğal (M) ve balıkçılıktan gelen ölüm (F) ile sömürülme oranları (E) sırası ile Z = 0,82, M = 0,38, F = 0,44 ve E = 0,57 $yıl^{-1}$ olarak hesaplanmıştır. Elde edilen bilgiler ışığında, tür için minimum avlama boyunun 14 cm, av sezon yasağının Ocak ile Nisan ayları arasında olması önerilmektedir. Sömürülme oranı dikkate alındığında, stok üzerindeki av baskısının normalin biraz üzerinde gerçekleştiği gözlenmektedir.

Anahtar Sözcükler: *Trisopterus minutus*, yaş, büyüme, ölüm, üreme, cinsi olgunluk boyu, Orta Ege Denizi

Introduction

Poor cod (*Trisopterus minutus* Linn., 1758) live in the eastern Atlantic (Trondheim Fjord and the Faeroe Islands to Portugal and along the Atlantic coast of Morocco) and the Mediterranean between the depths of 1 and 440 m (Cohen et al., 1990). Although the species occurs down to 440 m in its whole habitat, in the Mediterranean Sea, the poor cod is a typical neritic (shelf) species very close to both Mediterranean (*Trisopterus luscus*) and Atlantic (*Trisopterus esmarkii*) congeners. The poor cod belongs to the family Gadidae and its synonyms are *Brachygadus minutus*, *Gadulus minutus*, *Gadus capelanus*, *G. minutus*, *G. tacaud*, *Morua capelanus*, *Trisopterus luscus capelanus*, *T. minutus capelanus*, and *T. minutus minutus* (Cohen et al., 1990).

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Production of the poor cod has been reported under whiting (*Merlangius merlangus* Linn., 1758) in the Republic of Turkey Prime Ministry, Turkish Statistical Institute records. According to these records, the harvest from the Aegean Sea was 52 t in 2002 (TSI, 2004). Ragonese and Bianchini (1998) reported that smaller individuals are not discarded but marketed with the other species and this process is called "frittura" (fish to be fried). In Turkey these young poor cod are mixed with pelagic fishes (sardines, anchovies, etc.) and they are marketed jointly.

There are few studies on the biology of the poor cod. Planas and Vives (1952) and Vives and Suau (1956) studied the life history of the species in Spain. Giannetti and Gramitto (1988) studied the growth of the species that live in the central Adriatic Sea. Politou and Papaconstantinou (1991) wrote on the reproductive biology of the poor cod off the eastern coast of Greece. The first study on their reproduction length and feeding was done by Biagi et al. (1992); growth of the species, mortality, and yield-per-recruit (YPR) by Ragonese and Bianchini (1998); allozyme analyses, taxonomic situation of the species and population composition by Mattiangeli et al. (2000, 2003); feeding by Mattson (1990) and Morte et al. (2001); and recruitment dynamics by Lloret and Lleonart (2002).

This species is caught during the fishing of other economically important demersal fish species by trawling. In Turkey, there are no specific legal restrictions regarding the capture of this species. However trawls, the most effective fishing instrument for the species, are forbidden in the Aegean Sea between the beginning of April and the middle of July (MARA, 2004).

The objectives of the present study were to determine the age, sex distribution, growth in length and weight, gonadosomatic index, attainment of first maturity length, reproduction, mortality, and exploitation ratio of the poor cod in the central Aegean Sea. The data on these parameters are expected to be helpful in fisheries management of the poor cod.

Materials and Methods

The poor cod samples for the study were collected with trawl hauls from İzmir Bay (38°40'253''N 26°31'680''E and 38°2'727''N 26°8'542''E), between the depths of 30-70 m by R/V Egesüf (26.8 m length, 500 HP engine) from April 2001 through March 2002. A commercial bottom trawl was used for sampling. The cod-end used was diamond shaped and made of polyethylene (PE) material with 44 mm stretched mesh size netting.

Fish were measured in the natural body position for total length (TL) to the nearest mm and weighed (W, wet weight) to the nearest gram. Fish lengths were classified in 0.5 cm group intervals and length–frequency diagrams were drawn monthly. The female:male ratio was calculated for the population using the mature individuals after the elimination of immature ones. Chi-square test was used to determine the significance of the male to female ratio.

Otoliths were used to identify the sample ages. Considering their physical and chemical characteristics, the otoliths were prepared for age readings by profiling, rubbing, and polishing. They were imbedded in polyester moulds, cut by an Isomet Low Speed Saw, polished with sandpaper (type 400, 800, and 1200), and finally polished with 3, 1, and $^1/_4$ µ particulate alumina (Metin and Kınacıgil, 2001). Age determination was performed using a stereoscopic zoom microscope under reflected light against a black background. Opaque and transparent rings were counted: 1 opaque zone, together with 1 transparent zone, was considered the annual growth indicator.

Growth was analyzed by fitting the von Bertalanffy growth function to size-at-age data using standard nonlinear optimization methods (Sparre and Venema, 1998). The function $L_t = L_\infty[1-e^{-k(t-to)}]$ was applied to the data where L_t is the fish length (cm) at the time t (y), L_∞ is the asymptotic length (cm), k is the growth coefficient (y^{-1}), and t_o (y) is the hypothetical time at which the length is equal to zero. The accuracy of the growth parameters was tested using Munro's growth performance index ($\varphi' = \log(k) + 2\log(L_\infty)$) and t-test (Pauly and Munro, 1984).

Sex and maturity were determined by macroscopic analysis of the gonads. The maturity stages were assessed according to Gunderson's (1993) scale: stage I, immature; stage II, resting; stage III, developing; stage IV, ripe; and stage V, spent. Length at first maturity was defined as the length at which 50% of the population

investigated is near to spawning (King, 1996). The length at 50% maturity was determined with the L_{50} computer program by LogLog analysis (İlkyaz et al., 1998). The equations $r(l) = \exp(-\exp(-(a+bl)))$ and $L_{50} = (-\ln(-\ln(0.5))-a)/b$ were applied, where $r(l)$ (%) is the proportion of matures in each length class, l (cm) is the fish length, L_{50} (cm) is the mean length at sexual maturity (50%), a is intercept and b is slope.

Spawning period was established with monthly variations of the gonadosomatic index from the equation $GSI = [W_g/(W_t-W_g)]*100$, where W_g is the gonad weight (g), W_t is the total weight (g) of fish (Ricker, 1975). For fecundity, only gonads with hydrated oocytes were collected. Ovaries were stored in Gilson's fluid (100 ml 60% alcohol, 800 ml water, 15 ml 80% nitric acid, 18 ml glacial acetic acid, and 20 g mercuric chloride) to dissolve the connective tissue (Holden and Raitt, 1974). Egg numbers were estimated using the gravimetric method described by Bagenal (1978). For counting, approximately 0.5 g of eggs was taken from the anterior, middle, and posterior parts of the ovary. Counting was carried out under 40× magnification with a stereoscopic zoom microscope. The total number of eggs in the ovaries was then obtained from the equation $F = nG/g$, where F is fecundity, n is the number of eggs in the subsample, G is the total weight of the ovaries, g is the weight of the subsample in the same units. The relation between the total length and the number of eggs in a spawning batch was established as $F = aL^b$ and the relation between the fish weight and fecundity was determined as $F = aW+b$, where F is the fecundity, L is the fish length, W is the fish weight, and a and b are coefficients.

The survivors ratio (S) between N_{t+1} and N_t was employed to estimate the instantaneous rate of total mortality ($Z = -\ln(S)$) (Ricker, 1975). The natural mortality rate (M) was estimated from the following equation $M = \beta * k$, where β ranges between 1.3 and 2.1, and k is the growth coefficient (Jensen, 1996). β was estimated from the equation $\beta = (3-3\omega)/\omega$, where ω is the mean critical length to asymptotic length ratio according to fish family (for the Gadidae $\omega = 0.669$) (Cubillos, 2003). Following the estimation of the total (Z) and natural mortality (M), the fishing mortality rate (F) was estimated from $F = Z-M$, and the exploitation ratio (E) from $E = F/Z$.

Results

A total of 1527 individuals were sampled during the study period. It was determined that 53% of the fish were males (n = 809), 41% were female (n = 626), and 6% were immature (n = 92). The female:male ratio was calculated as 1:1.29 and chi-square analysis showed that it is statistically significant ($P < 0.05$).

Length–frequency relationship of the population is shown in Figure 1. The minimum size observed in September was 10.6 cm while the maximum size found in April had 24.8 cm total length. When the resultant graphics were examined attention was called to the new participants in the population beginning in July.

Age determination was performed using 414 individuals from all length and age classes (from I and V) (Table 1). The shortest one, a 1-year-old individual, in the samples was 10.6 cm and the longest one was a 5-years-old individual with a TL of 24.8 cm. The infinite length (L_∞) of all fish was 28.08 cm, $W_\infty = 254.03$ g, $t_0 = -1.52$ y, and $k = 0.26$ y^{-1} ($R^2 = 0.998$) (Table 2). The study's t-test showed that male, female, and total φ' values obtained were not significantly different compared to the available growth parameters estimated by other authors ($P > 0.05$) (Menon, 1950; Planas and Vives, 1952; Giannetti and Gramitto, 1988; Politou and Papaconstantinou, 1991; Ragonese and Bianchini, 1998; Jennings et al., 1999). Calculated average TL sizes for the year classes were 13.6, 17.0, 19.5, and 21.5 cm for 1-, 2-, 3-, and 4-year-old individuals, respectively (Figure 2).

Gonadosomatic index (GSI) values of females and males are given in Figure 3. The partial (heterochronal) spawning poor cod has a long reproduction period. In both sexes, gonads start to mature in October. In this month, females were in stages 1 and 2, while males were in stages 2 and 3. In December, both sexes were in stages 2 and 3. It was observed that reproduction was maximum in January and continued until April (Figure 4).

Fecundity calculations from the length of the specimens collected between December and April ranged between 13.6 and 24.5 cm and their average length was 18.6 ± 2.5 (TL ± sd). The number of eggs of these specimens ranged from 1236 to 21,463. The maximum fecundity value was found in the January samples. The relationship between fecundity length ($F = 1.29TL^{2.97}$, $R^2 = 0.72$) and fecundity weight was evaluated with gonads ($F_T = 0.11W-0.41$, $R^2 = 0.85$) or without gonads ($F_G = 0.12W-0.26$, $R^2 = 0.84$) as shown in Figures 5 and 6.

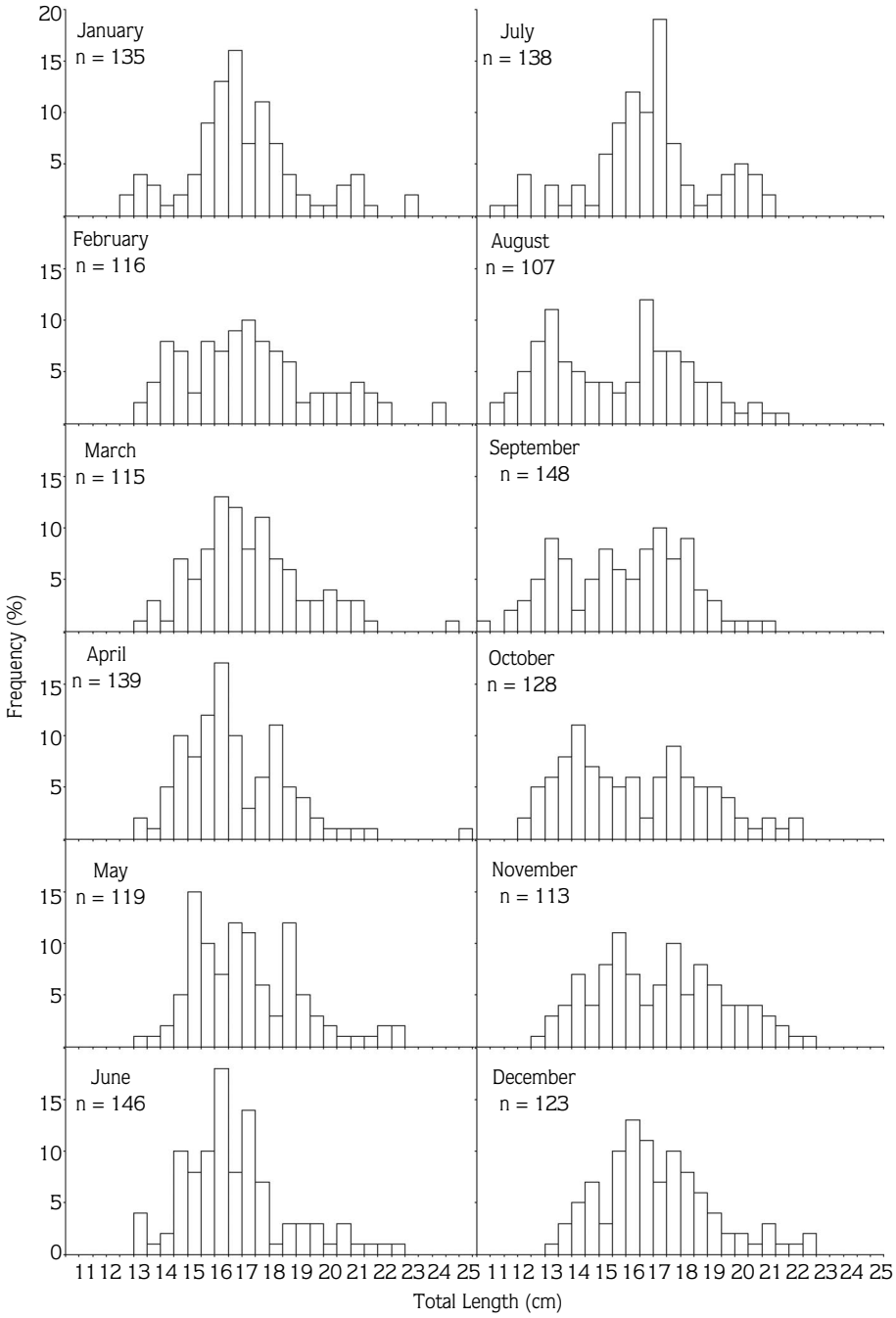

Figure 1. Total length–frequency distribution of the poor cod.

A total of 251 females, 425 males, and 77 immature individuals were used in the calculation of first reproduction length. The first mature gonad was found at 12.0 cm total length. A sigmoid relation was determined between the length and mature individual percentage for both sexes (male a = –5.358, b = 0.457, R^2 = 0.951; female a = –5.180, b = 0.418, R^2 = 0.974). Gonad maturity in 50% of the individuals was found at 13.3 cm total length for females and 12.5 cm for males (Figure 7).

Table 1. Age–length key of the poor cod for immatures (I), females (F) and males (M).

	Age Group														
	I			II		III		IV		V		Total			
LT	I	F	M	F	M	F	M	F	M	F	M	I	F	M	n
10.5	7	1										7	1		8
11	3	2										3	2		5
11.5	3	4	2									3	4	2	9
12	1	10	1									1	10	1	12
12.5		10	4										10	4	14
13		11	10										11	10	21
13.5		13	9										13	9	22
14		12	11										12	11	23
14.5		6	8	1	1								7	9	16
15		7	14	2	3								9	17	26
15.5		3	5	4	15								7	20	27
16		1	2	4	25								5	27	32
16.5			1	7	33								7	34	41
17				9	38								9	38	47
17.5				11	16								11	16	27
18				8	16								8	16	24
18.5				6	5	5							11	5	16
19				3		8	3						11	3	14
19.5				1		9							10		10
20						5							5		5
20.5						7							7		7
21						2			1				2	1	3
21.5						2							2		2
22								1					1		1
22.5								1					1		1
23															
23.5															
24															
24.5															
25										1			1		1
	14	80	67	56	152	38	3	2	1	1	0	14	177	223	414
		161		208		41		3		1					

Table 2. The von Bertalanffy growth parameters for the poor cod.

	n	L_∞	W_∞	k	t_0	R^2
Male	223	24.999	166.183	0.298	-1.752	0.998
Female	176	26.886	227.426	0.330	-1.092	0.988
All fish	414	28.078	254.032	0.263	-1.516	0.998

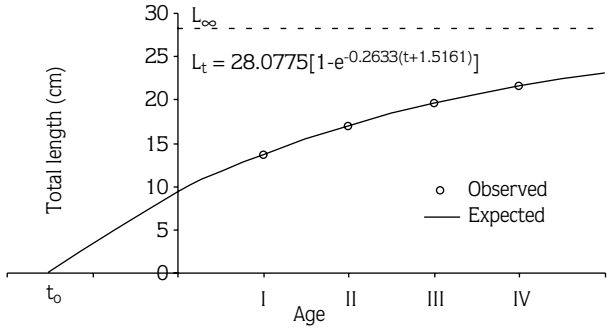

Figure 2. The von Bertalanffy growth curve for the poor cod.

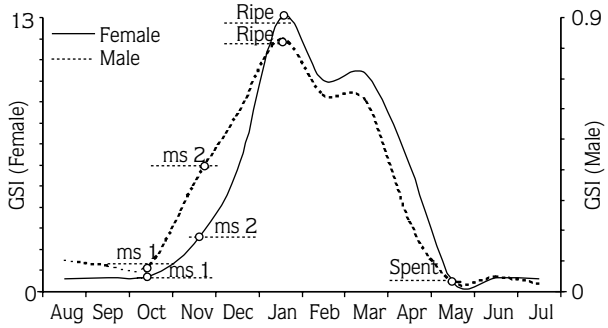

Figure 3. Gonadosomatic index (GSI) values (%) of males and females by month for the poor cod.

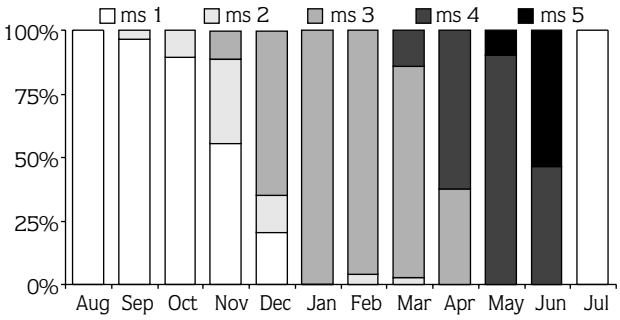

Figure 4. Percentages of different maturity stages (ms) per month for the female poor cod.

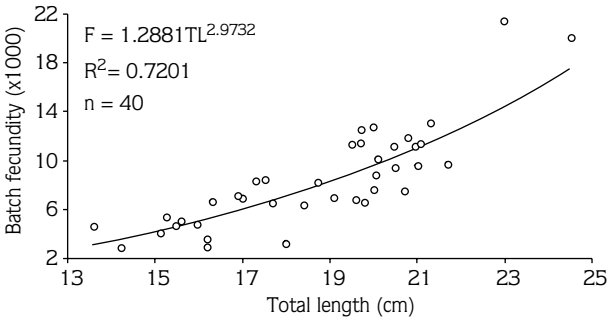

Figure 5. Fecundity–total length relationship for the poor cod.

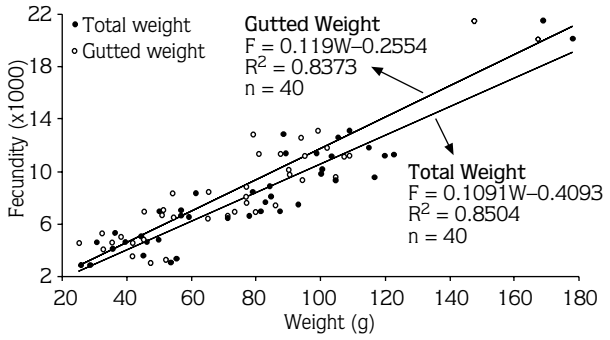

Figure 6. Fecundity–weight relationship for the poor cod.

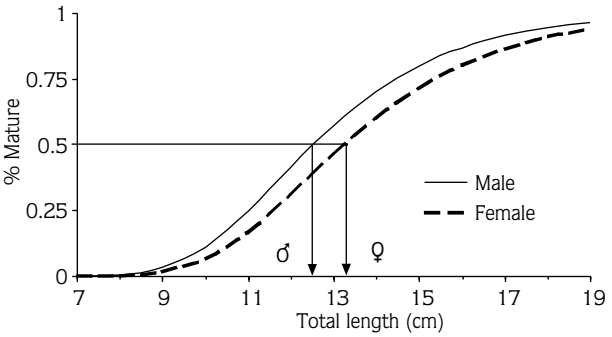

Figure 7. Length at first maturity estimation of the poor cod.

The total, natural, and fishing mortality rates and the exploitation rate were: Z = 0.82 year^{-1}, M = 0.38 year^{-1}, F = 0.44 year^{-1}, and E = 0.57, respectively.

Discussion

A total of 1527 individuals were investigated in the study to determine the stock characteristics of the poor cod in the central Aegean Sea (İzmir Bay). The shortest individual, 10.6 cm, was obtained in September and the

largest individual was found in April with a 24.8 cm total length. Politou and Papaconstantinou (1991) defined 5 cm total length as the minimum length group in the Euvokies Bay (Greece) in September. Also, the maximum length was found to be 27 cm by the same researchers in June. In our study, utilisation of 44 mm legal mesh size at the cod-end of the trawl can be considered the reason for the absence of smaller individuals in this sampling.

The female:male ratio was calculated as 1:1.29. Politou and Papaconstantinou (1991) found this ratio as 1:1.66 (0.60), and Tangerini and Arneri (1984) defined it as 1:2.17 in May and 1:3.23 in November. The sex ratio varies considerably from species to species, differs from one population to another of the same species and may vary from year to year in the same population (Nikolsky, 1963). It is likely that the deviations between our study and the previous ones were caused by these factors.

In this species, it was difficult to see and read the age rings without extra processing of the otoliths; therefore, profiling, rubbing, and polishing have been applied to the samples to determine their ages. It was found that the age composition of the population was between 1 and 5. Ragonese and Bianchini (1998) have reported that the life cycle of the species is 4 to 6 years and it was described by the same authors as a small-sized and short-lived fish.

Males were longer in the early life stages than females, but in later stages females were longer than males (male age I = 14.0, II = 16.8, III = 18.9, IV = 20.5 and female age I = 13.4, II = 17.2, III = 19.9, IV = 21.9 cm TL), which is in line with the studies carried out by Menon (1950), Giannetti and Gramitto (1988), and Politou and Papaconstantinou (1991). Therefore, L_∞ value of the previous studies and our study was higher in females. Growth performance index (φ') of the females was also higher than that of the males. The growth performance index of the poor cod was found to be 2.31 for the total population. Other indices of other geographic areas are given in Table 3. As shown in this table, although the growth parameters L_∞ and K values were different, growth performance index of the poor cod populations ranged from 1.35 to 2.38 and they were relatively similar to each other except in Giannetti and Gramitto (1988), which was calculated by a different method. The t-test showed that there is no significant difference between the overall growth performances of male, female and total samples from the other areas ($P > 0.05$).

Table 3. A comparison of previous studies withthe present study for the von Bertalanffy growth parameters and the Munro's φ' index of the poor cod.

	Area	L_∞	k	t_0	φ'	Author
Male	Central Adriatic Sea (Italy)	23.6	0.04	-4.78	1.35	Giannetti and Gramitto, 1988
	Eastern Coast of Greece	23.3	0.32	-1.62	2.24	Politou and Papaconstantinou, 1991
	English Channel	20.0	0.42		2.23	Menon, 1950*
	Central Aegean Sea	25.0	0.30	-1.75	2.27	Present study
Female	Central Adriatic Sea (Italy)	24.7	0.07	-0.35	1.63	Giannetti and Gramitto, 1988
	Eastern Coast of Greece	33.5	0.18	-1.83	2.31	Politou and Papaconstantinou, 1991
	English Channel	24.0	0.40		2.36	Menon, 1950*
	Central Aegean Sea	26.9	0.33	-1.09	2.38	Present study
Total	Strait of Sicily	22.2	0.46	-0.68	2.36	Ragonese and Bianchini, 1998
	Eastern Coast of Greece	32.3	0.18	-1.87	2.27	Politou and Papaconstantinou, 1991
	North Sea	20.0	0.51		2.31	Jennings et al., 1999*
	Vinaroz and Columbretes Is.	22.0	0.39		2.28	Planas and Vives, 1952*
	Central Aegean Sea	28.1	0.26	-1.52	2.31	Present study

* From Cohen et al. 1990.

Maturation of the partial spawning poor cod starts in December, reaches its maximum in January, and continues until April. This pattern was determined by observing the gonadosomatic index graphic and maturity stages graphics (Figures 3 and 4). Other studies have also shown that the poor cod spawns for a long period of the year. It was reported by Planas and Vives (1952) and Vives and Suau (1956) that it is between January and May on the east coast of Spain; by Froglia (1981) from January and May and by Tangerini and Arneri (1984) from January to June in the Adriatic Sea; by Politou and Papaconstantinou (1991) (spent and ripe gonads) during almost all seasons along the coast of Greece; by Ragonese and Bianchini (1998) between December and May in the Strait of Sicily; by Relini et al. (1999) between winter and spring in the western Mediterranean. Also it can be said that, as shown on the length–frequency graphic (Figure 1), recruitment occurs in a 3-month period between July and September.

Minimum reproduction length for the stock was also calculated. In females, it was found at 13.3 cm and in males 12.5 cm total length and these values coincided at about first age in both sexes. Froglia (1981), Tangerini and Arneri (1984), and Fischer et al. (1987) reported the first reproduction length at 13 cm and in 1-year-old fish for the total population. In North Tirenian Sea, the first reproduction length was calculated at 13.8 and 12.39 cm total length for females and males, respectively, by Biagi et al. (1992) and these values coincide with our study.

Fecundity varied from 1236 eggs (1-year old) to 21,463 eggs (5-year old) and it correlated significantly with fish length, weight, age, and gonad weight (Blaxter, 1969). A large fish lays more eggs than a small one, and the correlation of fecundity with the weight of fish is higher than that with the length and age (Nikolsky, 1969). Additionally, it differs between populations of the same species and does not remain constant from year to year (Erdoğan et al., 2002). Since no data are available on the fecundity–length and fecundity–weight relationships, the results could not be compared with them.

The total (Z), natural (M), fishing mortality (F), and exploitation rates (E) were estimated at Z = 0.82, M = 0.38, F = 0.44 y^{-1} and E = 0.57. Mortality and exploitation rates are important for understanding the the future of the stock. The exploitation rate for all fish in the present study is slightly high. Gulland (1971) suggested that, as a rule of thumb, 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 central Aegean Sea is being exploited higher than the optimal level.

In conclusion, this study determined the sex ratio, some growth parameters (L_∞, t_o, and k), age composition, fecundity, and spawning period for the poor cod from the central Aegean Sea. Notwithstanding that the poor cod is a commercial species in Turkey, there is no information about minimum landing size or the prohibited season in the fishing circular of the Republic of Turkey Ministry of Agriculture and Rural Affairs (MARA, 2004). In light of these results and evaluations, for the continuity and improved yield of the poor cod population in the central Aegean Sea, fish smaller than 14 cm must not be caught. In addition, fishing should be prohibited from January to April and the present fishing effort can be partly decreased in the fishing season.

Acknowledgments

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