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# Some Aspects of the Reproductive Biology of Poor Cod (*Trisopterus minutus capelanus* Lacépède, 1800) in Edremit Bay (the North-Eastern Aegean Sea)

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**Abstract**

Aspects of the reproductive biology of poor cod were studied from samples collected by bottom trawl in Edremit Bay during September 1999 and December 2000. A total of 3904 poor cod specimens were investigated consisting of 1946 females, 1576 males and 382 individuals with unidentified sex. The sex ratio (males to females) of poor cod varied from 0.34 to 1.27 and significant differences were found in the unity (1:1) among months. The reproductive period started in December and continued throughout spring. The main spawning was in February and March. The length at maturity of female observed to be 11.4 cm while the smallest mature female was 10.8 cm. Batch fecundity was found to be highly variable between individuals and ranged from 765 to 7958 eggs (mean: 2295 eggs, SD: 968 eggs). Batch fecundity increased with fish length and weight. Relative fecundity varied between 41 and 116 eggs/g (mean: 76 eggs/g, SD: 12 eggs/g) for the fish weight ranged from 14.2 to 83.6 g.

*Keywords:* Poor cod, the north-eastern Aegean Sea, spawning period, length at maturity, fecundity.

**Edremit Körfezi'nde (Kuzeydoğu Ege Denizi) Tavukbalığının (*Trisopterus minutus capelanus* Lacépède, 1800) Üreme Biyolojisinin Bazı Yönleri**

**Özet**

Edremit Körfezi'nden Eylül 1999 ile Aralık 2000 tarihleri arasında dip trolü ile toplanan örneklerle tavukbalığının üreme biyolojisinin bazı yönleri çalışılmıştır. Toplamda incelenen 3904 tavukbalığının 1946'sı dişi, 1576'sı erkek ve 382'si cinsiyeti tanımlanamayan bireylerden oluşmuştur. Tavukbalığının cinsiyet oranı (erkeklerin dişilere oranı) 0,34 ile 1,27 arasında değişim göstermiş ve cinsiyet oranının aylar arasında varsayılan (1:1) oranından önemli farklılıklar gösterdiği bulunmuştur. Üreme dönemi aralık'ta başlamış ve ilkbahar boyunca devam etmiştir. Yumurtlamanın büyük kısmı şubat ve mart aylarında olmuştur. Dişi bireyler için cinsel olgunluk boyu 11,4 cm olarak hesaplanmış iken, en küçük olgun dişi bireyin boyu 10,8 cm'dir. Bir defada bırakılan yumurta miktarının (verimliliği) bireyler arasında 765 yumurtadan 7958 yumurtaya kadar (ortalama: 2295 yumurta, SD: 968 yumurta) oldukça yüksek bir değişim gösterdiği bulunmuştur. Yumurta verimliliği, balık boyu ve ağırlığı ile artış göstermiştir. Göreceli doğurganlık değeri 14,2 g ile 83,6 g arasında yer alan balık ağırlıkları için 41 ile 116 yumurta/g (ortalama: 76 yumurta/g, SD: 12 yumurta/g) arasında değişmiştir.

*Anahtar Kelimeler:* Tavukbalığı, Kuzeydoğu Ege Denizi, yumurtlama dönemi, olgunluk boyu, yumurta verimliliği-doğurganlık.

## Introduction

The poor cod (*Trisopterus minutus capelanus* Lacépède, 1800) is distributed along the eastern Atlantic and in the Mediterranean Sea from the Mediterranean coast of Morocco to the eastern coast of Spain, along the Italian peninsula in the Adriatic, and the coast of Tunisia, the Ionian and Aegean Seas as well as along the coasts of Israel while it is absent from much of the North African coast (Svetnovidov *et al.*, 1986; Fischer *et al.*, 1987; Choen *et al.*, 1990). This benthopelagic fish is found in small schools on sandy and muddy bottoms from 20 m to over 400 m in depth, but mostly from 40 m to 120 m (Relini *et al.*, 1999).

Although poor cod is not of great commercial importance, its ecology and biology have been studied by many researchers in different regions of the Mediterranean Sea, probably due to its abundance in the demersal ecosystem (Biagi *et al.*, 1992; Relini *et*

*al.*, 1999). Some of the biological studies on poor cod have included information on reproductive biology, especially in terms of spawning period and length at maturity ((Planas and Vives, 1952; Vives and Suau, 1956; Froglia, 1981; Froglia and Zoppini, 1981; Tangerini and Arneri, 1983; Biagi *et al.*, 1990; Politou and Papaconstantinou, 1990; Biagi *et al.*, 1992; Metin *et al.*, 2008). Of these studies only that of Metin *et al.* (2008) focused on the fecundity of poor cod. .

The aim of this study is to make a contribution to the reproductive biology of poor cod in the northeastern Aegean Sea. The paper considers spawning period, length at maturity and the fecundity.

## Materials and Methods

Poor cod samples were collected by bottom trawl in the Edremit Bay between September 1999 and December 2000 (Figure 1). The sampling area has been closed to the bottom trawl fishery since 1995. With the permission from governing authorities a total of 65 trawls were hauled at depths ranging from 38 m to 86 m during 12 sampling surveys. The trawl cod-end was 22 mm in mesh size (knot-to-knot) throughout the sampling process.

Poor cod individuals were randomly sampled after each trawl operation on the deck and preserved in 4 % formalin. Each specimen was measured to the nearest mm for total length (TL), weighed with a precision of ±1 g, dissected and sexed macroscopically. The gonads of the female fish were also weighed with a precision of ±0.0001 g. In each sampling month, the sex ratio was calculated and a chi-square ($\chi^2$) goodness of fit test was used to detect if the proportion of males and females was significantly different from 1:1. A chi-square ($\chi^2$) contingency table analysis was also used to determine whether there was any difference in the sex ratios among the sampling months (Zar, 1996).

The reproductive period was established from the monthly distributions of the percentage frequency of Gonad Maturity Stages (GMS) and Gonadosomatic Index (GSI). GMS was assessed macroscopically using a four stage key (which is simplified from the Holden and Raitt's (1974) five-point maturity scale for partial spawners): I immature; II developing; III mature (ripening and ripe) and IV spent. GSI was calculated (GSI=[Weight of gonads/ Weight of fish]*100) only for females with a size larger than the length at maturity. GMS and GSI were not evaluated for male poor cod because of assigning maturity stages of male gonads were not reliable by the naked eye and they were easily damaged during the removal process.

Length at maturity ($L_{50}$) was also estimated for only females from the percentages of the mature individuals in the reproductive period. The size at which 50% of fish were mature was calculated by the following logistic function (King, 1995):

$$P = \frac{1}{1 + e^{-r(L - L_{50})}}$$

where P is the proportion of mature fish at size L and r the curvature parameter, which were all calculated using non-linear least squares estimation.

Batch fecundity (number of oocytes released per spawning) was gravimetrically estimated by the hydrated oocyte method (Hunter *et al.*, 1985). A total of 218 gonads (160 in January-February, 58 in March) with hydrated oocytes were analysed to estimate batch fecundity. Various sizes of oocytes were present at the same time within reproductively active gonads and hydrated oocytes were easily recognizable. Mean batch fecundity was calculated by the following equation:

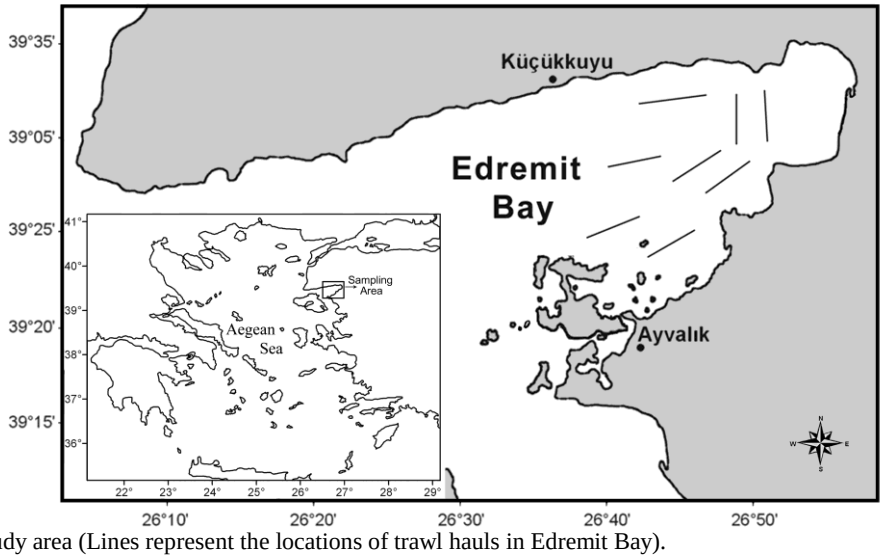


**Figure 1.** Study area (Lines represent the locations of trawl hauls in Edremit Bay).

$$\overline{BF} = \frac{\sum_{i=1}^{n} \left( \frac{\sum_{j=1}^{3} \frac{HON_{ij}}{SSW_{ij}}}{3} \right) \times OW_i}{n}$$

where $\overline{BF}$ is the mean batch fecundity, $OW_i$ the ovary weight of fish i, $HON_{ij}$ the number of hydrated oocytes sub-sample j from fish i, $SSW_{ij}$ the weight of sub-sample j from fish i and n the total number of fish analysed for fecundity calculation.
Relative fecundity was calculated as the ratio of the batch fecundity to the ovary free weight. .
The relationship between the batch or relative fecundity (F) and fish total length (TL) was based on the function of $F=a\ TL^{b}$ (Wootton, 1990).

## Results

A total of 3904 poor cods consisting of 1946 females, 1576 males and 382 unidentified, were investigated in this study. The length range of females (5.2 to 24.2 cm) was wider than of males (6.5 to 20.2 cm). The majority of poor cod ranged between 9.0 and 17.0 cm in both sexes and larger individuals were rare (Figure 2). The smallest individual (2.3 cm, unidentified sex) was caught in March, and the proportion of individuals smaller than 9.0 cm gradually increased through later months until end of summer (Figure 2).

Sex ratios varied from 0.34 to 1.27 and, were found to be statistically different among the sampling months ($\chi^2$=91.78, df=11, P<0.05) (Table 1). In general, sex ratios were in favour of females during autumn months and were significantly different from the unity (1:1). The proportions of males began to increase in the late winter and exhibited a more abundant distribution pattern in spring. The distributions of both sexes were nearly equal in the months of March, April and May and there was no significant difference from the unity (1:1) (Table 1).

Gonad development of female poor cod started in the autumn (October and November) and the first matured individuals (stage III) were captured in December (Figure 3). Gonad maturation continued through February and March. Percentage of mature individuals showed an important decrease in April. Specimens with spent gonads were only found in April, May and June (Figure 3).

The spawning period of poor cod varied with fish size. In December, the beginning of spawning period, the mature females ranged from 14.7 to 20.0 cm and the majority (82 %) were larger than 17.0 cm. Smaller females were also found to be mature in the following months. In February, March and April, different sized females were mature and their length ranges were 10.8-24.2 cm, 11.0-18.2 cm and 12.6-19.0 cm, respectively. In May, the end of spawning period, the smallest mature female was 14.6 cm as observed in December. These results suggest that the larger females become mature earlier and their spawning period take longer than the smaller individuals.

GSI values showed unimodal distribution and seemed to be corroborated by the results of GMS. The GSI values began to increase in November and reached its highest values in February and March (Figure 4). This period with high GSI values indicates an intensive spawning period of poor cod in Edremit Bay. The GSI decreased in April and May and remained at very low values throughout the summer and autumn.

Length at maturity ($L_{50}$) of female poor cod estimated from the logistic model fitted to the data was about 11.4 cm, while the smallest mature female was 10.8 cm in Edremit Bay (Figure 5).

The batch fecundity was found to be highly variable between individuals and ranged from 765 to 7958 eggs (mean: 2295 eggs, SD: 968 eggs) for fish ranging in total length from 11.0 to 20.0 cm. The batch fecundity increased with length and gonad free fish weight (Figure 6). While the lowest mean batch fecundity was 1093±308 (SD) eggs for the smallest length class, larger individuals can produce approximately three or four times more eggs.

The relative fecundity varied between 41 and 116 eggs/g (overall mean: 76 eggs/g, SD: 12 eggs/g) for fish weighing from 14.2 to 83.6 g (Figure 6).

## Discussion

Results presented in this study show that the reproductive biology of poor cod is similar to those of other studies performed in the different regions of the Mediterranean Sea with the exception of length at maturity. While length distributions were in a range of 2.3-24.2 cm, only a few large individuals were caught during this study which are similar to that of other studies conducted in the Mediterranean Sea (Planas and Vives, 1952; Vives and Suau, 1956; Froglia, 1981; Tangerini and Arneri, 1983; Politou and Papaconstantinou, 1990; Biagi *et al.*, 1990; Biagi *et al.*, 1992; Relini *et al.*, 1999; Metin *et al.*, 2008). Larger individuals were reported by Froglia and Zoppini (1981) and Politou and Papaconstantinou (1990) over a broader area and in deeper water than surveyed in this study. Some of the above-mentioned studies noted that large individuals usually migrated into deep water (Biagi *et.al.*, 1990; Politou and Papaconstantinou, 1990). Lack of larger individuals in the present study may be related to the migration of these individuals to deep regions outside of Edremit Bay.

In the present study, sex ratio of poor cod was observed to be variable with significant differences from the unity (1:1) among months. Generally, sex ratio was in favour of females especially during

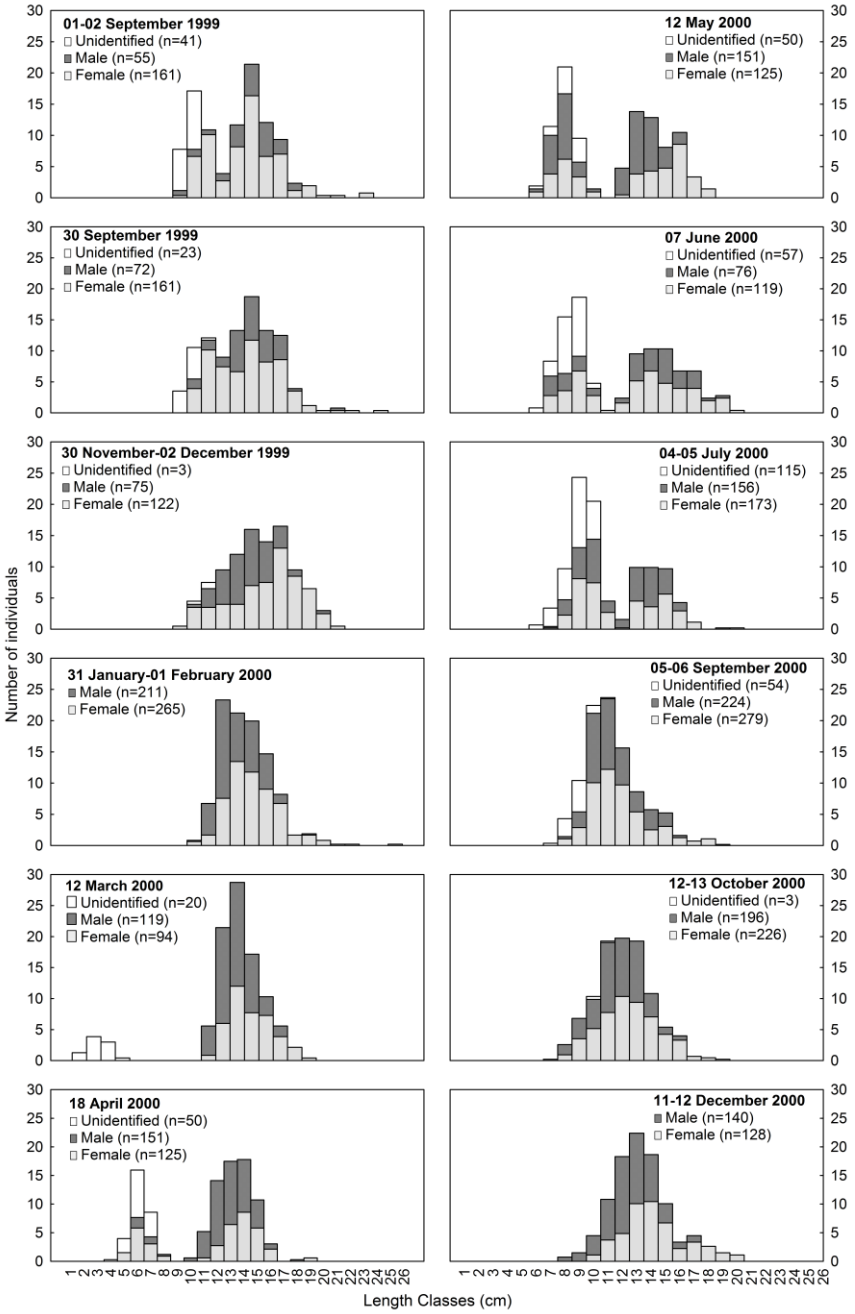


**Figure 2.** Length-frequency distribution of poor cod by sampling months in Edremit Bay.

summer and autumn. Distributions of both sexes became almost equal in spring. Spring coincides with the spawning period of poor cod and can be explained by the migration of male poor cod as a reproductive behaviour from deep to the area that the samplings were carried out. Similarly, females were also prevalant in the Southern Tuscany Archipelago. and the sex ratios varied by length and depth. Interestingly small-sized males were dominant within 100 m whereas females were more abundant in depths over 100 m (Biagi *et al.*, 1990). .

As far as the spawning period is concerned, the results of this study are similar to those obtained in different regions of the Mediterranean Sea and noted that poor cod propagate from late winter to the end of spring (Planas and Vives, 1952; Vives and Suau, 1956; Froglia, 1981; Tangerini and Arneri, 1983; Politou and Papaconstantinou, 1990; Biagi *et al.*, 1992; Relini *et al.*, 1999; Metin *et al.*, 2008). This is also supported by the presence of small-size (<9.0 cm) individuals in the spring and summer catches in Edremit Bay.

Poor cod individuals, larger than 14.5 cm, have a long spawning period from December to June, while smaller individuals (<14.5 cm) exhibited a shorter spawning period, mainly in February and March in Edremit Bay. Similarly, Biagi *et al*., (1992) noted that only large females were mature at the beginning of

**Table 1.** Monthly variations of sex ratio of poor cod in Edremit Bay (Asterisks represents the following probability ranges: *=0.05 ≥P>0.01, **=0.01≤P>0.001, ***=P≤0.001)

| Sampling Period | Sex ratio (♂:♀) | $X^2$ |
|---|---|---|
| 01-02 September 99 | 0.34 | 52.02*** |
| 30 September 99 | 0.45 | 34.00*** |
| 30 November-02 December 99 | 0.61 | 11.21*** |
| 31 January-01 February 00 | 0.80 | 6.13* |
| 12 March 00 | 1.27 | 2.93 |
| 18 April 00 | 1.21 | 2.45 |
| 12 May 00 | 1.15 | 0.89 |
| 07 July 00 | 0.64 | 9.48** |
| 04-05 June 00 | 0.90 | 0.88 |
| 05-06 September 00 | 0.80 | 6.01* |
| 12-13 October 00 | 0.87 | 2.13 |
| 11-12 December 00 | 1.09 | 0.54 |

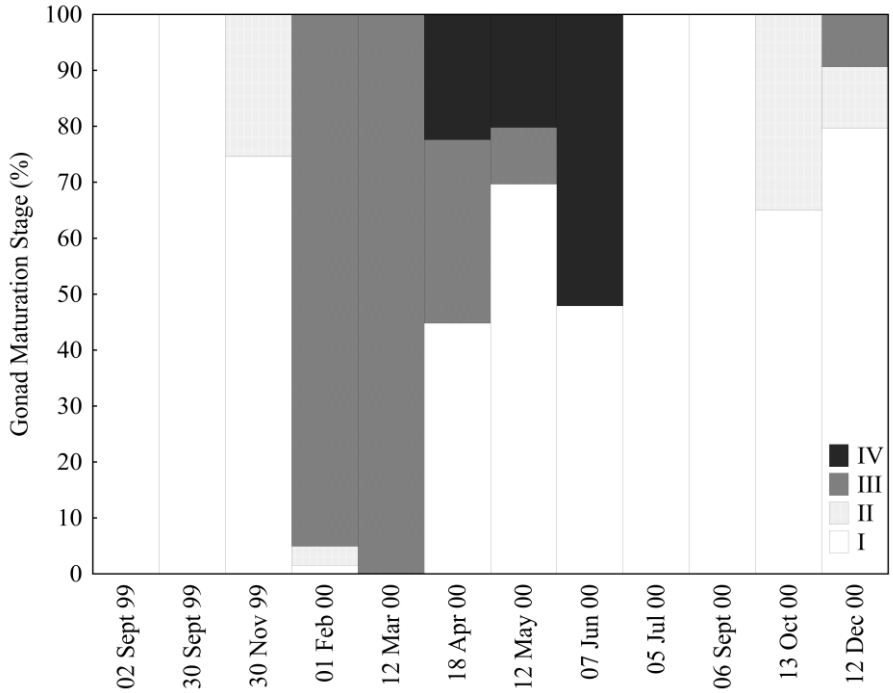


**Figure 3.** Percentage distribution of gonad maturation stages by sampling months in Edremit Bay. (I:immature, II:developing, III:mature(ripening and ripe) and IV:spent).

the spawning season with smaller females became progressively mature in the following months. The ecological importance of this adaptation seems to be related to the fact that large females may produce larger size eggs and larvae than small females that are able to feed on larger prey as small size prey are scarce in early spring (Biagi *et al.*, 1992).

Because females are observed to be mature for a long period from December to May, it is possible to say that poor cod is a serial spawner. The co-occurrence of various sizes of oocytes within reproductively active ovaries confirms that an individual female may spawn more than once during the reproductive period (Murua and Saborido-Rey, 2003). This spawning strategy has been mentioned by other investigations in the Mediterranean Sea (Planas and Vives, 1952, Vives and Suau, 1956; Froglia, 1981; Politou and Papaconstantinou, 1990; Biagi *et. al.*, 1992, Metin *et al.*, 2008).

It is well known that a relatively long reproductive period provides have some advantages increasing possibilities to survival of eggs and larvae by reducing the negative influences of biotic factors such as prey availability, larval competition, predation effects and undesirable environmental conditions (Wright and Trippel 2009). Politou and Papaconstantinou (1990) pointed out this tactic and summarized the reproductive strategy of poor cod as a combination of early maturation, extended spawning season, serial spawning, high fecundity and extensive

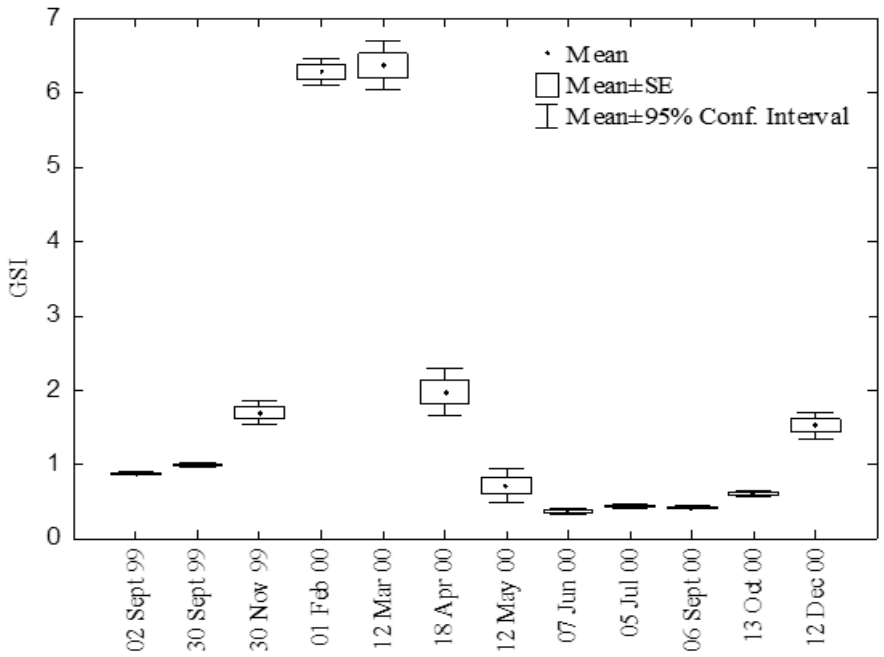


**Figure 4.** Gonadosomatic Index (GSI) values of poor cod by sampling months.

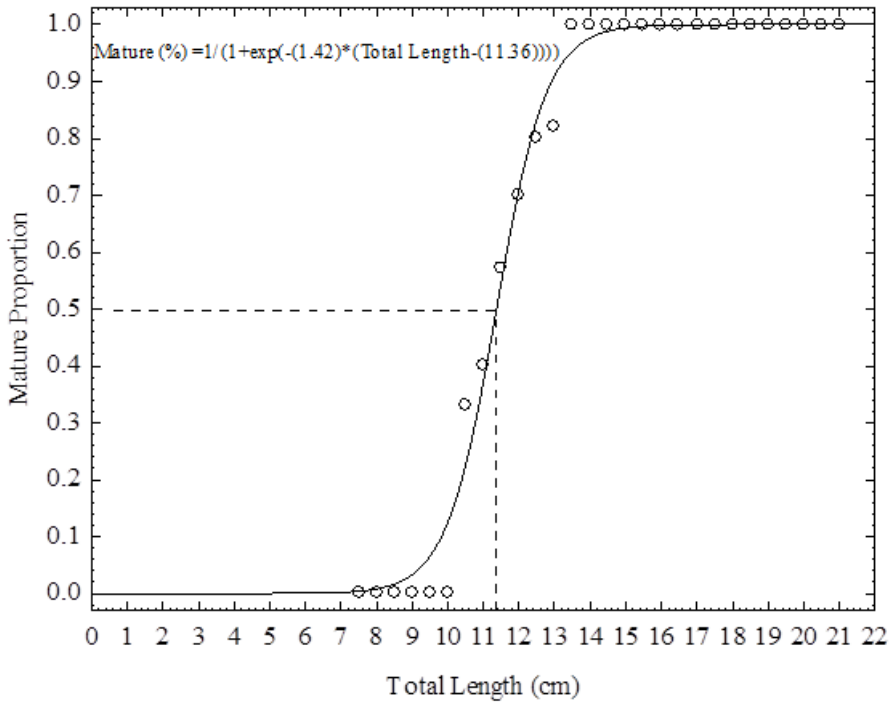


**Figure 5.** Logistic regression model for the estimated proportion of sexually mature female poor cod as a function of total length in Edremit Bay.

migration across the continental shelf during spawning.

Previous studies have shown that poor cod reached first maturity at the end of the first year of their life with an approximate size of 13-14 cm for females in different regions of the Mediterranean Sea (Froglia, 1981; Tangerini and Arneri, 1983; Politou and Papaconstantinou, 1990; Biagi *et al.*, 1992; Metin *et al.*, 2008). In the present study, length at maturity was estimated as 11.4 cm for females and did not correspond to other studies in the Mediterranean Sea. The current findings suggest that female poor cod may reach sexual maturity at a smaller size than that reported by other studies. The reason for this is

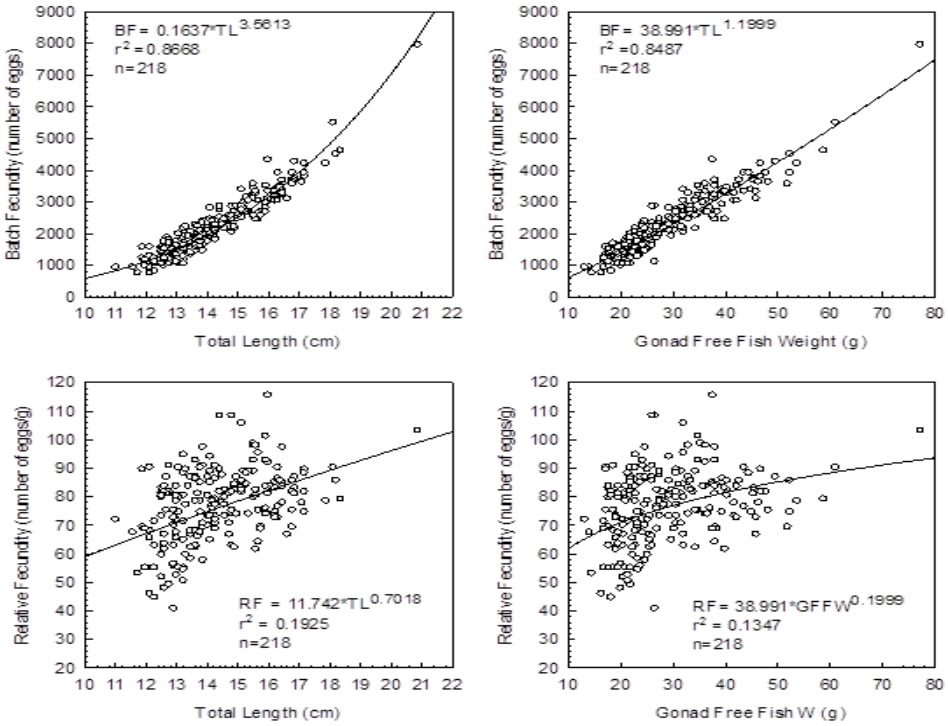


**Figure 6.** Relationships between fecundity (batch and relative) and fish body length, ovary free body weight of poor cod.

related to the size structure of the mature individuals in the present data set. The smallest mature individual (10.8 cm) is smaller than that of other studies and the proportion of small mature individuals was very high. The length at maturity in all other studies was estimated by using the data covering the whole reproductive period. As mentioned before, the reproductive period for the small individuals is short. No small-size mature female was caught in December, so they possibly get mature in the following months. This reproductive feature affects the proportion of small-sized mature individuals negatively and may lead to larger $L_{50}$ values, as documented by other investigators (Trippel, 1995).

Additionally, small $L_{50}$ may be related to high natural and/or fishing mortality of large individuals. Although the sampling area has been closed to the bottom trawl fishery, small-scale fisheries activities still continue in the bay. Size at first maturity may have been reduced as a result of harvesting the larger fish by a more selective fishery and as well as the migration of large poor cod into deeper waters out of the sampling area. Similarly, Sattar *et al.* (2008) highlighted that earlier maturation evolved when fisheries selected larger fish. It is also stated by Jennings *et al.* (2001) that long-term fishing pressure may cause earlier maturation to ensure opportinities of spawning prior to exploitation.

The information on the fecundity of poor cod in the Mediterranean Sea is very limited. Metin *et al.* (2008) estimated batch fecundity between 1236 eggs and 21463 eggs for fish ranging from 13 to 25 cm total length in the Central Aegean Sea. The batch fecundity estimates in the present study were slightly lower and observed as strongly dependent on fish size. In terms of relative fecundity, the egg production of females per g ovary free weight was similar at different length classes.

The relative fecundity of poor cod in Edremit Bay varied between 41 and 116 eggs/g. Since no data are available on relative fecundity of poor cod, the results could not be compared with others. But, for a congeneric species, pouting (*T. luscus*) Alonso-Fernández *et al.* (2008) recently reported a range of relative fecundity from 5 to 67 eggs/g for fish between 108 to 366 g on the Galician shelf of north-western Spain in the Atlantic Ocean. Although poor cod has a relatively smaller size distribution than pouting, it appears that higher relative fecundity is related to the size structure of the oocytes.

In conclusion, some of the reproductive parameters such as sex distribution, gonad development, spawning period and batch fecundity of the poor cod population in the north-eastern Aegean Sea are very similar to the findings of other studies in the Mediterranean Sea, while the estimate of $L_{50}$ in the present study is considerably smaller. Finally, these findings improve our understanding of the reproductive strategy of the poor cod population from the north-eastern Aegean Sea.

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