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Use of Otolith Length and Weight in Age Determination of Poor Cod (*Trisopterus minutus* Linn., 1758)

Gülnur METİN, Akın Türker İLKYAZ*
Ege University, Fisheries Faculty, 35100 Bornova, İzmir - TURKEY

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Abstract: Totally 189 poor cod (*Trisopterus minutus* Linn., 1758) specimens were collected by trawling in the central Aegean Sea between April 2001 and March 2002. The relationship of the otolith length and weight with the age of poor cod was investigated, as the age determination is relatively difficult by otolith readings. There was a linear relationship between the fish length (LT) and the otolith length (L_o), i.e. $L_o = 0.421\ LT + 1.659$ ($R^2 = 0.998$), a linear relationship between the fish age (T) and the otolith weight (W_o), i.e. $W_o = 0.041\ T - 0.030$ ($R^2 = 0.994$), and a power relationship between the otolith length (L_o) and the fish age (T), i.e. $L_o = 13.663\ (1 - e^{-0.271(t + 1.815)})$($R^2 = 0.997$). The applicability of these relationships in age determination of poor cod was investigated and it was concluded that the relationship between the otolith weight and the fish age could be used in age determination of the species, with practical estimation, easy comparison, and low error rate.

Key Words: Poor cod, *Trisopterus minutus*, otolith, age

Tavuk Balığında (*Trisopterus minutus* Linn., 1758) Otolit Boyu ve Ağırlığının Yaş Belirlemede Kullanımı

Özet: Toplamda 189 adet tavuk balığı (*Trisopterus minutus* Linn., 1758) örneği Nisan 2001 – Mart 2002 tarihleri arasında, Orta Ege Denizi'nden trol avcılığı ile toplanmıştır. Otolit okuması nispeten zor olan tavuk balığının otolit boyu ve ağırlığının yaş ile olan ilişkisi incelenmiştir. Balık boyu (LT) – otolit boyu (L_o) arasında $L_o = 0{,}421\ LT + 1{,}659$ ($R^2 = 0{,}998$) ve yaş (T) – otolit ağırlığı (W_o) arasında ise $W_o = 0{,}041\ T - 0{,}030$ ($R^2 = 0{,}994$) şeklinde doğrusal bir ilişki olduğu, otolit boyu (L_o) – yaş (T) arasında ise $L_o = 13{,}663\ (1 - e^{-0{,}271\ (t + 1{,}815)})$ ($R^2 = 0{,}997$) şeklinde üssel bir ilişki olduğu tespit edilmiştir. Bu ilişkilerin tavuk balığının yaşının belirlenmesinde uygulanabilirliği araştırılmış ve otolit ağırlığı – balık yaşı arasındaki ilişkinin değerlendirme pratikliği, karşılaştırma kolaylığı ve düşük hata oranı ile türün yaşının tespitinde kullanılabileceği sonucuna varılmıştır.

Anahtar Sözcükler: Tavuk balığı, *Trisopterus minutus*, otolit, yaş

Introduction

The age composition of a fish stock is an important parameter used in stock assessment models in fisheries management. Age determination in bony fishes can be carried out by counting seasonal growth annuli appearing on hard structures such as the otolith, scale, fin ray, and spine. Otolith is the most preferred of these structures.

Age determination in fish can be carried out with direct (direct observation on hard structures) or indirect (marking and recapture, length-frequency analysis etc.) methods (Morales-Nin, 1992). Generally the direct observation technique is based on the investigation of the whole otolith's surface. Although this technique seems reliable, it may give rise to erroneous age determinations in older fish, and in otoliths with excessive calcium-carbonate accumulation (Metin and Kınacıgil, 2001). An accurate age determination depends on the reader's skill, whereby this is closely associated with experience and an amount of bias in age estimations of different readers (Sandeman, 1969; Ernst et al., 1995). In addition,

* E-mail: akin.ilkyaz@ege.edu.tr

manpower and time spent in ageing with this method are considerable (Cardinale et al., 2000). For those reasons, alternative methods requiring less effort and delivering larger precision are sought for determining the ages of fish. One of these alternative methods is the relationship of the otolith size/weight and fish growth. Härkönen (1986) found that there is a high correlation between fish length and otolith length, and that this relationship is usually linear. Brander (1974), on the other hand, claimed that otolith weight has a direct relationship with the age of the fish; this hypothesis was supported by Spratt (1972), who stated that fish sampled from slowly growing populations have larger otoliths as per size when compared to fish of the same length. More recently, several researchers found a strong relationship between the age of the fish and otolith size and weight (Boehlert, 1985; Pawson, 1990; Fletcher, 1991; Fowler and Doherty, 1992; Worthington et al., 1995).

Poor cod (*Trisopterus minutus* Linn., 1758) belongs to the family Gadidae and it is caught in Turkey by gillnet, purse seine, and trawl. This species lives between depths of 30 and 300 m and smaller individuals prefer shallow waters. The species is distributed naturally along coastal Europe from Trondheim to Gibraltar and down to Morocco and the Western Mediterranean (Svetovidov, 1986).

Politou and Papaconstantinou (1991) used a back-calculation method obtained from the measurement of cross-sectioned otoliths in age determination of the species. On the other hand, Giannetti and Gramitto (1988) determined age on cross-sectioned otoliths through direct observation. Biagi et al. (1992) and Ragonese and Bianchini (1998) used ELEFAN software in estimating the ages of the individuals using the length–frequency relationship. The fact that no age determination has yet been carried out by direct method, without applying any additional techniques before reading, is due to the difficulty related to ageing by otolith readings.

In this study, the relationships between otolith length and weight, and the age of the poor cod were investigated as well as their potential to be used in age determination of the species.

Materials and Methods

The poor cod individuals were collected from İzmir Bay (central Aegean Sea) (38°40'253''N 26°31'680''E and 38°22'727''N 26°48'542''E), between the depths of 30 and 70 m by R/V "Egesüf" (26.8 m length, 500 HP engine) in April 2001-March 2002. The commercial bottom trawl was used for sampling. The cod-end used was made of polyethylene (PE) material, diamond shaped, 44 mm stretched mesh size netting.

Total length (LT) was measured and the sagittal otoliths of 189 individuals were removed. The fish length measurements were recorded with 1 mm precision. The otolith lengths were measured by electronic calliper with 0.01 mm precision, while the weights were measured with electronic scales with 0.0001 g precision. Otoliths were removed in pairs for any probable damage or loss during the measuring process. The otoliths were preserved dry in u-plates and measurements were always obtained from undamaged otoliths (Figure 1).

Before the age reading process, the otoliths were sectioned, sanded, and polished to enhance the visibility of growth zones. They were embedded into polyester moulds and then sectioned using an Isomet Low Speed Saw. Thereafter otoliths were polished with sandpaper (type 400, 800, and 1200) and finally polished with 3, 1, and $^{1}/_{4}$ µ particulate alumina. Age was read by a stereoscopic zoom microscope under reflected light against a black background (Figure 2). Opaque and

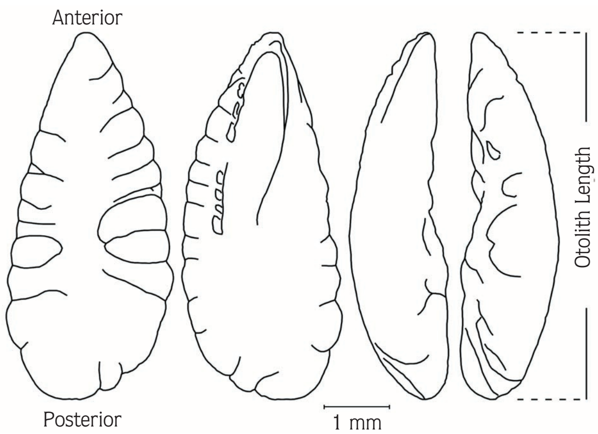

Figure 1. General view of poor cod otolith.

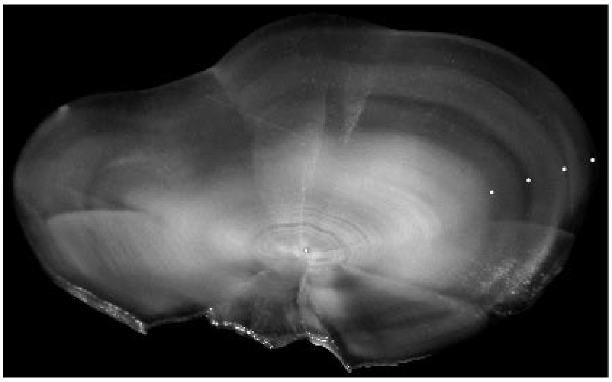

Figure 2. View of the sectioned, sanded, and polished otolith in a 4-year-old poor cod of 22.1 cm LT.

transparent rings were counted; 1 opaque zone and 1 transparent zone together were considered 1 annual. Otoliths were read at least twice.

The relationship between fish age and otolith length was investigated by fitting the von Bertalanffy (1938) growth function to size-at-age data using standard nonlinear optimisation methods. The function $L_o = L_\infty(1 - e^{-k(t - to)})$ was used, where L_o is the otolith length (mm) at time t (year), L_∞ is the asymptotic otolith length (mm), k is the growth coefficient ($year^{-1}$), and t_o (year) is the hypothetical time at which otolith length is equal to zero. The linear equation y = ax + b was used in the calculation of the age–otolith weight and fish length–otolith length relationships.

Results

It was determined that the poor cod specimens ranged between 10.8 and 22.5 cm in length, and were between 1 and 4 years of age. The most dominant age class was 2, with 50.8%, followed by 1 (29.6%), 3 (18.0%), and 4 (1.6%) years of ages (Table 1).

There are linear relationships between fish length (LT) and otolith length (L_o), L_o = 0.421 LT + 1.659 (R^2 = 0.998), and between age (T) and otolith weight (W_o), W_o = 0.041 T – 0.030 (R^2 = 0.994) (Figure 3).

The maximum asymptotical otolith length of the species was 13.7 mm (L_∞), the theoretical age of the fish prior to hatching from the egg was –1.8 (t_o), and the growth coefficient was 0.3 (k) when the average otolith length values corresponding to each age class were analysed with the von Bertalanffy growth function (R^2 = 0.997) (Figure 4).

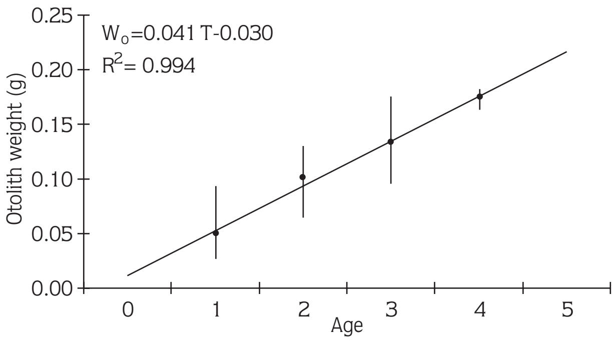

Figure 3. Relationship between age and otolith weight in poor cod.

Discussion

A total of 189 individuals consisting of 1- to 4-year-old individuals were examined in this study. Politou and

Table 1. Distributions of the samples in terms of age, item, fish length, otolith length, and weight.

Age	n (%)	LT_{min}	LT_{max}	LT_{mean} ± se	LO_{min}	LO_{max}	LO_{mean} ± se	WO_{min}	WO_{max}	WO_{mean} ± se
1	56 (29.6)	10.8	15.4	13.45 ± 0.15	6.31	8.68	7.29 ± 0.08	0.0270	0.0936	0.0485 ± 0.0022
2	96 (50.8)	15.2	18.5	16.85 ± 0.09	7.90	9.93	8.83 ± 0.04	0.0647	0.1299	0.0989 ± 0.0016
3	34 (18.0)	18.2	21.4	19.80 ± 0.15	8.85	11.04	9.91 ± 0.09	0.0961	0.1756	0.1330 ± 0.0032
4	3 (1.6)	21.9	22.5	22.17 ± 0.18	10.71	10.98	10.84 ± 0.08	0.1632	0.1820	0.1739 ± 0.0056

n: number of fish. %: rate in total. LT: fish length (cm). LO: otolith length (mm). WO: otolith weight. min: minimum. max: maximum. mean: average. se: standard error.

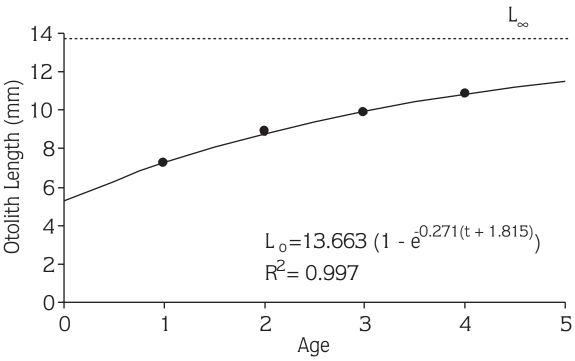

Figure 4. Age–otolith length relationship in poor cod.

Papaconstantinou (1991) found 1- to 5-year-old individuals in a study carried out along the eastern coast of Greece. Ragonese and Bianchini (1998) reported the life cycle of the species to be 4-6 years and described it as a small-sized and short-lived fish. In our study, the use of 44 mm legal mesh size at the cod-end of the trawl may be the major reason for the absence of smaller individuals (0+) in the samples.

Here we show that there is a strong linear relationship between fish length and otolith length (R^2 = 0.998). Casselman (1990) reported that the relative size of calcified structures provides a sensitive indicator of growth. Considering this close relationship, it has been taken into account that the von Bertalanffy growth equation used in explaining the relationship between fish length and age can also be used in explaining the relationship between otolith length and age, and a relationship with high correlation was obtained (R^2 = 0.997).

Politou and Papaconstantinou (1991) used a back-calculation method using the measurements taken from cross-sectioned otoliths in determining the ages of poor cod samples collected from the eastern coast of Greece, and length averages were 13.0, 16.2, 18.9, 21.1, and 22.9 cm (LT) for age 1 to 5, respectively. Giannetti and Gramitto (1988) used a cross-sectioning method in determining the ages of individuals living in the central Adriatic Sea, using both sexes. Therefore, the results are inadequate for an objective comparison as they did not determine the relationship between age and length for the total and they used individuals in the calculations of both sexes whose sexes were not known. Biagi et al. (1992) and Ragonese and Bianchini (1998) used ELEFAN software using the length-frequency method in estimating the relationships between the ages and lengths of individuals in the northern Tyrrhenian Sea and in the Strait of Sicily.

Biagi et al. (1992) combined age values with the maturity levels but they did not present the relationship between age and length. The ages were estimated as 12.0, 15.8, 18.1, 19.6, and 20.6 cm (LT) respectively starting from 1 year of age using the equation given by Ragonese and Bianchini (1998). Our data confirmed previous studies on the age-length relationship. However, Munro's growth performance index ($\varphi' = \ln(k) + 2\ln(L_\infty)$) used in comparing these parameters cannot be applied here since our estimations were carried out on otolith size.

Although it is possible to explain the relationship between otolith length and age with the von Bertalanffy growth function, determination of the relationship between age and otolith length through 3 different parameters (L_∞, k, and to) affects the use of this model in age determination. Fletcher (1991) stated that age determination based on length is suitable only for rapidly growing species or juveniles of slowly growing species because the relative increase in size between the age classes becomes less with age compared with the variation in size within each age class. For that reason, many researchers have highlighted the close relationship between age and otolith weight, and dwelled on the potential use of this relationship in age determination. Boehlert (1985) revealed that age can be accurately determined through measuring other variables besides otolith weight. Cardinale et al. (2000) stated that there is a strong relationship between otolith weight and age in Pleuronectes platessa and Gadus morhua, and recommended this technique since it is objective, economical, and easy to perform in age determination. Our study showed that there is a strong linear relationship between age and otolith weight in poor cod (R^2 = 0.994). Although no similar study appears to have been carried out on poor cod, our results support the results obtained by different researchers on other species.

In conclusion, the applicability of strongly correlated relationships between otolith length and age, and between otolith weight and age in age determination was investigated, and it was concluded that the relationship between otolith weight and age could be used in age determination of the species, with practical estimation, easy comparison, and low error rate.

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