RESEARCH ARTICLE

A study on the growth of horse mackerel (*Trachurus mediterraneus* Aleev, 1956) from Bulgarian waters of the Black Sea using length frequency analysis

Maria Yankova[*]

Institute of Oceanology, Bulgarian Academy of Sciences, Department of Marine Ecology and Biology, 40 First of May Street, Po. B. 152, 9000 Varna, BULGARIA

[*]**Corresponding author:** maria_y@abv.bg

Abstract

Length frequency data of horse mackerel *Trachurus mediterraneus ponticus* were collected from commercial net catch from Bulgarian Black Sea waters. Sampling covered the fishing season from May to December in 2012. FISAT II software program was used to analyze its length frequency distribution. The corresponding values of asymptotic length L_∞ using ELEFAN I ranged from 18.11 and 19.26 cm, K values were 0.51 year^{-1} and 0.44 year^{-1}, for males and females, respectively. L_∞ estimated by Bhattacharya and Ford-Walford method ranged from 18.90 and 19.11 cm for males and females, respectively. Meanwhile, L_∞ by Wetherall and Bertalanffy method shows 18.24 and 18.78 cm for males and females, respectively. The instantaneous rate of total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated and accordingly the exploitation ratio was determined. The Z estimated by length cohort analysis ranged from 1.42 for females and 1.62 for males. The Beverton relative yield per recruit model analysis showed that E_{MSY} the maximum (Y'/R), was obtained at nearly the same value for females =(0.37) and males (0.38).

Key words: Population parameters, mortality, exploitation rate, horse mackerel, Black Sea.

Introduction

Family Carangidae in the Black Sea is represented by *Trachurus trachurus* and *Trachurus mediterraneus ponticus*. In the Bulgarian Black Sea territorial waters only *T. mediterraneus ponticus* is present. Entering of *T. trachurus* specimens to the Black Sea from the Sea of Marmara is a quite rare phenomenon (Stoyanov *et*

al. 1963). The systematic situation of the Black Sea mackerel was carefully examined by Numann (1956) and Aleev (1952, 1957). The same authors stated that in the Black Sea the species was represented by four local subpopulations: the south western (Boshopric), the northern (Crimean), the eastern (Caucasian) and the southern (Anatolian), each one with its own biological characteristics such as wintering grounds, fat content, spawning patterns, age composition, growth rate and feeding patterns.

On the basis of investigation carried out by Georgiev and Kolarov (1959, 1962) on size composition and also tagging experiments of horse mackerel caught off the Bulgarian coast, they concluded that in the Black Sea two subpopulations (the eastern and western ones) occur that belong to the small size-type of *Trachurus mediterraneus ponticus*. Although in the past the Black Sea horse mackerel has been attributed to various subpopulations, in a more recent study, Prodanov *et al.* (1997) presented evidence that the horse mackerel rather exists as a single population in the Black Sea, and thus all Black Sea horse mackerel fished across the region should be treated as one stock.

Dobrovolov and Dobrovolova (1983), using electrophoresis methods, assumed that no difference at species level can be found between *T. mediterraneus ponticus* and *T. m. mediterraneus*. For this reason, Dobrovolov (1986) reported that the large size-type occurrence can be explained as a result of heterosis effect between the above-mentioned subspecies. This type being sterile does not produce further offspring and becomes extinct after completing its life span (Prodanov *et al.* 1997).

Examination of age and growth is very important in ichthyological investigations, because fish growth is one of the four main factors (others being recruitment, natural mortality coefficient and fishing mortality coefficient) determining the stock conditions (Mikhailov and Prodanov 2003). Population parameters and growth of horse mackerel were investigated by Ivanov and Beverton (1985), Prodanov *et al.* (1997), Tichonov (1955), Şahin *et al.* (1997), Turan (2004), Yankova and Raykov (2006) and Yankova *et al.* (2010).

The goal of the present paper is to establish the values of the length growth parameters of the species under investigation, with the aim to determine its natural mortality coefficient for the investigated period.

Materials and Methods

Length frequency data of horse mackerel were collected from trawl and fishing net catches in the Bulgarian Black Sea territorial waters (Figure 1).
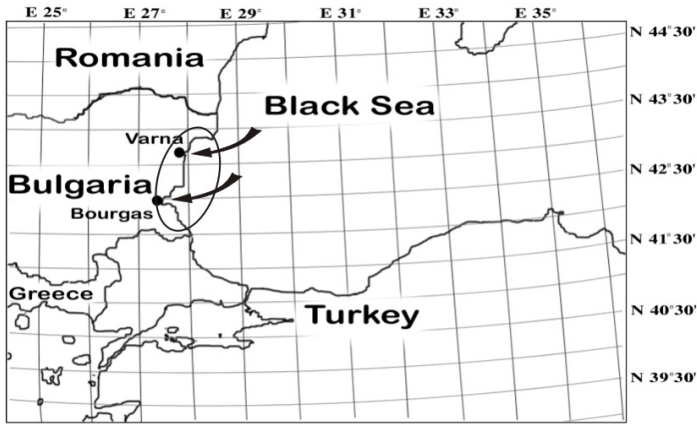
Figure 1. Locations of the main landing sites along the Bulgarian
Black Sea coast

A total of 11200 specimens of *T. mediterraneus* were collected during the period from May 2012 through December 2012. Total length was measured to the nearest cm and grouped into 0.5 cm length groups. The FISAT II was applied for data analysis (Gayanilo and Pauly 1997). For each sex the length frequency was resolved into normally distributed cohort components using Bhattacharya (1967) method and the result were used as input to Ford (1933)-Walford (1946) plot to estimate the asymptotic length (L_∞ in cm) and the rate at which the asymptotic length was attained (K, in year^{-1}). The Ford-Walford plot is a graph of the following equation: $L_{t+1} = L_\infty (1 - e^{-K}) + e^{-K} L_t$.

Where L_t and L_{t+1} are the total length of the fish at age t and t+1, respectively. By plotting L_t against L_{t+1}, the resulting slope $b = e^{-K}$ and the intercept $a = L_\infty (1 - e^{-K})$. The growth parameters were also estimated using the ELEFAN I program. Total mortality (Z) was estimated using the cumulated catch curve. Natural mortality (M) was calculated from Pauly's (1980) following multiple regression formula: $\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$, where M is natural mortality in a given stock, L_∞ is asymptotic length, K is growth coefficient and the value of T is the annual mean temperature (in °C) of the surface water. Non seasonal growth parameters, L and K, were estimated with Von Bertalanffy growth formula by the FISAT II computer programme. The fishing mortality (F) was computed as $F = Z-M$ and the exploitation rate was computed from the rate $E = F/Z = F/(F+M)$ (Gulland 1971). The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984). The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated by using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986).

Results and Discussion

Length Frequency Distribution

The horse mackerel length frequency distribution for May, June, July, August, September, October, November and December combined during 2012 is shown in Figure 2. In 2012, the largest percentage of female (21.6%) is within the length classes of 12 cm and that of males is within the size classes 14.5 cm (14.8%).The observed maximum length was 18 cm for females and 16.5 cm for males.
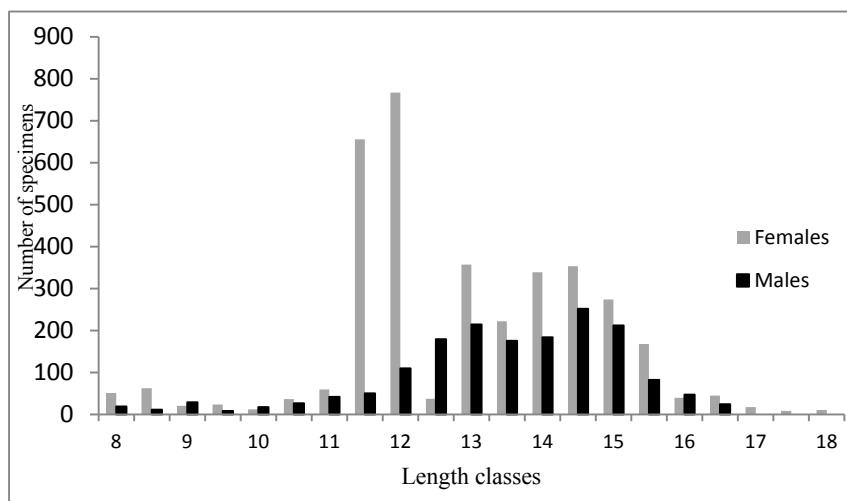
Figure 2. Horse mackerel length frequency distribution in the Bulgarian Black Sea during 2012

Population Parameters

Growth in Length

In the present work, the growth was examined for males and females separately. These results show that L_∞ values for females were higher than those for males. Weatherley (1972) indicated that this may be due to the faster growth rate of females and that the life span of females is longer than that of males. Raykova-Petrova and Zivkov (1987) reported that the interrelationship between the growth rate and asymptotic length was inversely proportional, as in the present investigation. Zivkov *et al.* (1999) identified the biological reasons for the unsuitability of growth parameters and indices in comparing growth rates, including the absence of biological significance at such high levels of L_∞, as well as growth self-regulation and compensation. According to Weatherly

(1972), this may be a result of the faster growth rate of females compared to males, and that the life span of females is longer than that of males. The food size, quantity and quality, as well as water temperature are closely linked to the growth parameters of the population (Santic *et al.* 2002).

Growth Parameters

The mean lengths for cohorts estimated by the Bhattacharya method for males and females were fitted into Ford-Walford plot to estimate the growth parameters. The obtained values of K were 0.37 and 0.32 year^{-1} for males and females, respectively, while L_∞ was 18.90 and 19.11 cm for males and females, respectively. Table 1 shows the growth parameters estimates obtained by ELEFAN I program and Wetherall method.

Table 1. Growth parameters of horse mackerel in the Bulgarian Black Sea

Method	Males		Females		Sexes combined	
	K year^{-1}	L_∞ (cm)	K year^{-1}	L_∞ (cm)	K year^{-1}	L_∞ (cm)
Bhattacharya and Ford-Walford	0.37	18.90	0.32	19.11	0.71	18.95
ELEFAN I program	0.51	18.11	0.44	19.26	0.53	19.10
Wetherall and Bertalanffy plot	0.58	18.24	0.49	18.78	0.61	18.73

The value of K for males was higher than that for females, which indicated the faster decrease in growth rates of males than females. The values obtained were consistent with those reported in previous studies (Table 2).

Table 2. Summary of the growth parameters (L_∞, K and t_o) for the horse mackerel in different localities

Location	Sex	Age years	L_∞ (cm)	K year^{-1}	t_0	Author
Bulgarian Black Sea	Male	1 – 5	18.78	0.34	-0.825	Yankova *et al.* 2010
	female	0 – 6	19.66	0.31	-0.836	Yankova *et al.* 2010
	Total	0 – 6	19.60	0.30	-0.877	Yankova *et al.* 2010
Turkish Black Sea Coast	Total	1 – 6	18.36	0.43	-0.598	Şahin *et al.* 1997
Bulgarian Black Sea	Total	-	19.25	0.35	-0.591	Prodanov *et al.* 1997
Bulgarian Black Sea	Total	1 – 5	19.99	0.31	-0.491	Yankova and Raykov, 2006

Mortality and Exploitation Rate

The results (Figure 3) indicated that the total mortality coefficient differred between sexes (Z= 1.61 yr^{-1} for males and 1.42 yr^{-1} for females). These high values of Z are considered reasonable because most of fisheries around the world have high fishing mortalities and thus show high Z values (Garcia and Le Reste 1981; Garcia 1984, 1985). The values of M obtained were 0.86 and 0.70

for males and females, respectively. The values of fishing mortality rate F were 0.75 year^{-1} for males and 0.72 year^{-1} for females while the exploitation rate was estimated as 0.47 for males and 0.51 for females. The values of mortality coefficient calculated in the present study for females and males could not be compared with those of previous studies due to the absence of available data. The same species may have different natural mortality rates in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities (Sparre and Venema 1998). Even small changes in the growth parameters used could seriously affect the computed mortality rates (Tserpes and Tsimenidis 2001).

Females **Males**
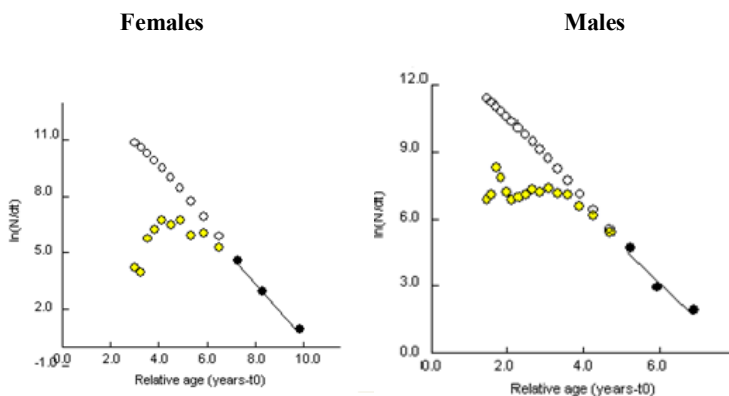
Figure 3. Length converted catch curve of *T. mediterraneus* in the Black Sea. Length converted catch curve, the darkened full dots represent the points used in calculating through least square linear regression and the open dots represent the point either not fully recruited or nearing to L_∞

Length at First Capture

The lengths at first capture (the length at which 50% of the fish are vulnerable to capture) were estimated as $L_{50\%}$=14.5 and 14 cm for females and males, respectively (Figure 4).

Per-Recruit Analysis and Reference Points

The plot of relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for females and males (Figure 5) showed that the maximum (Y'/R) was obtained at nearly the same value of E (E_{MSY}=0.37 for females and 0.38 for males). Both of E $_{0.1}$ and E $_{0.5}$ were estimated and the obtained value were 0.30 and 0.24 for females and 0.46 and 0.32 for males, respectively. The estimates of both values were lower than the current E which was also higher than that giving the maximum Y/R. For resource management

purposes, it is suggested that the exploitation rate should be reduced to the conservative ones ($E_{0.1}$ or $E_{0.5}$).

Females　　　　　　　　　　　　　　**Males**
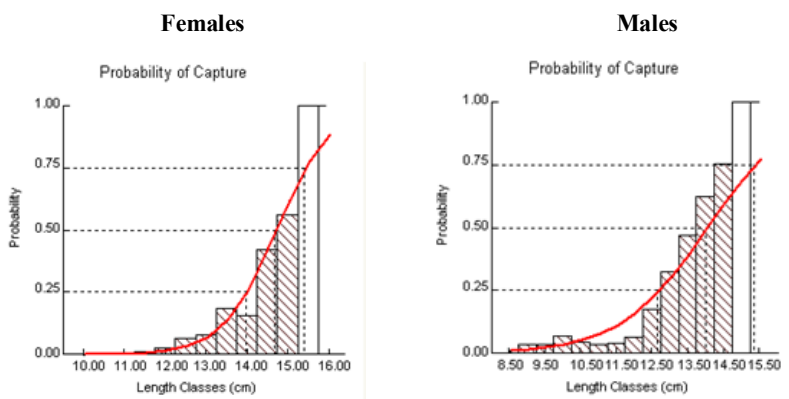
Figure 4. Logistic selection curve showing 25%, 50% and 75% selection length (cm TL) of *T. mediterraneus* (broken lines) in the Bulgarian Black Sea

Females　　　　　　　　　　　　　　**Males**
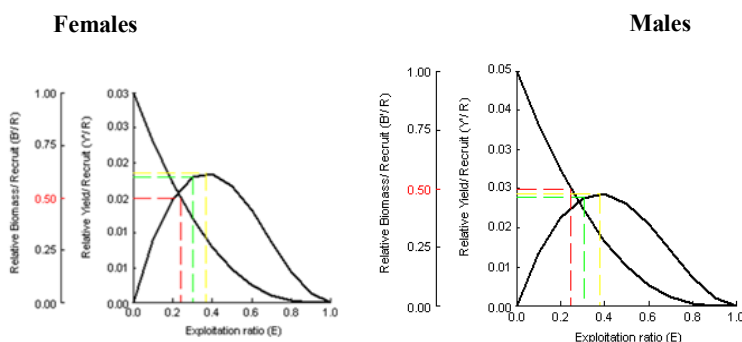
Figure 5. Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices: E_{OPT} -optimum yield, E_{MEY} - maximum economic yield and E_{MSY} – maximum sustainable yield of exploitation for *T. mediterraneus* in the Bulgarian Black Sea

This analysis showed the general trend of length distribution and growth of *Trachurus mediterraneus*. The present study indicated that is unable to provide a biological reference point consistent with high long term yield or to quantify the exploitation rate. Therefore, complementary studies are required.

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