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SPATIO-TEMPORAL VARIATIONS OF LENGTH, TOTAL WEIGHT AND BODY CONDITION INDEX OF THE MEDITERRANEAN HORSE MACKEREL FROM THE ROMANIAN BLACK SEA AREA

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Abstract

The purpose of this study was the analysis of spatio-temporal variations of length, total mass and the Fulton condition factor (useful index for monitoring feeding intensity) as well as of the length-total mass relationship, which is an important parameter, which helps to know the growth pattern of fish populations. A number of 1200 individuals from the Trachurus mediterraneus species (Steindachner, 1868) that were collected from pelagic trawls and stationary uncovered pound nets along the Black Sea coastal area in the periods 2013-2015 and 2018-2020 were analysed. The average lengths and weights were 11.4 ± 2.3 cm and 14.0 ± 8.3 g, respectively, and the minimum and maximum values were 3.0 and 19.0 cm in length and 0.6 and 61.2 g in weight. The value of exponent b in the equation is 2.9485, indicating that the weight increase is allometrically positive. The mean value of the Fulton was 0.84 ± 0.11, and the minimum and maximum values were 0.42 and 1.74. The average length and average weight were significantly correlated with the Fulton index (r = - 0.069; p = 0.017, respectively r = 0.168; p < 0.0001). The total length and the Fulton index of horse mackerel varied significantly between stations and between years and months, which is most likely due to seasonal variations, as well as trophic differences between areas.

Key words*: biometric measurements, Fulton index, length-weight relationship, statistical analyses.*

INTRODUCTION

The ichthyofauna of the Black Sea has undergone significant changes in the last 60 years, both in the qualitative and quantitative structure, as well as in the behaviour of the different species (Nicolae et al., 2018). These changes are, most probably, the consequences of human activities, both directly through fishing pressure and indirectly through the deterioration of environmental conditions. The Black Sea basin is characterised by the fact that most fish occupy large areas in exclusive areas of the riparian countries and make feeding and spawning migrations throughout the basin. In this connection, the Romanian coastline occupies an important place, being known for its role in feeding and reproduction of the main species, although the biomass of catches obtained in this area is quite low.

The continuing decline in populations of many fish species, including horse mackerel, is mainly due to the deterioration of the habitats necessary for their survival. In a few decades, the intensification of many human activities, such as agriculture, industry, energy, transport and tourism, has led to the loss or fragmentation of natural habitats (Yatsu, 2019). For centuries, traditional forms of agriculture or traditional fishing activities have represented a way of efficient resource management (FAO, 2020). The abandonment of these activities and their application on an industrial scale, without studying the resilience limits of natural fish populations, has led to a depletion of stocks, biodiversity and changes in the landscape.

The horse mackerel *Trachurus mediterraneus* (Steindachner, 1868) is a member of the Carangidae family and represents a large part of the amount of fish caught in the Black Sea

basin (Cocan & Mireșan, 2018). Species of the *Trachurus* genus are pelagic fishes of economic importance. A small pelagic species, the horse mackerel is also important to Romanian fisheries for economic and social reasons.
The biological characteristics of horse mackerel have been previously characterised in different areas of the Black Sea. Prodanov et al. (1997) studied the growth and estimated the optimum exploitation level of horse mackerel along the Bulgarian coast. Yankova & Raykov (2006) reported data for growth parameters and natural mortality coefficient of this species in Turkiye. Ambroaz (1954) investigated the distribution, migratory patterns, and catch composition. The biology of this species along the Romanian coast was reported in 1979 by Cautis & Ionescu and by Păun et al. (2019a; 2019b; 2020; 2021). Despite the significant number of studies on horse mackerel, there is a lack of recent data on the morphometry and reproduction of this species on the Romanian coast.
This scientific research analyses a time series (2013-2015 and 2017-2020) of data from pelagic trawls and stationary fishing nets found along the Black Sea coast, with the aim of analysing the spatio-temporal variations of the main biological parameters (length and total weight and the condition factor).
In particular, length-weight relationships have important applications in fisheries science and population dynamics, such as length-weight conversion for biomass estimation, building stock assessment models and estimating fish health status (Froese, 2006). In addition, they allow the monitoring of seasonal variations in fish growth and the comparison of morphological traits and life history between species or populations in different habitats and regions (Richter et al., 2000). Indices or condition factors are widely used to study the biology of fish because they provide relevant information about the psychological state of fish, based on the principle that individuals of a given length that are heavier are in better condition (Craig et al., 2005).
Environmental fluctuations are thought to strongly influence the abundance of pelagic species and can also lead to changes in life history and growth patterns; therefore, data collected from long-term studies are essential for determining average growth parameters (Bellido et al., 2000).
This scientific research contributes to improving information on the biology of horse mackerel in Romanian Black Sea waters in order to develop sustainable management measures for these species (Păun et al., 2021).

MATERIALS AND METHODS

The study area was located in the northwestern and southern part of the Black Sea (Figure 1).

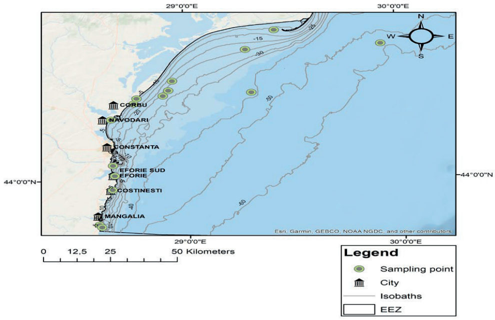

Figure 1. Study area (Original by ArcMap)

For this study, 1200 individuals were collected from pelagic trawls and uncovered stationary fishing nets along the Black Sea coast in the northern area (Gura Portiței, Periboina, Vadu, Corbu, Platforme, Cap Midia, Camp Năvodari Camp, Năvodari, Mamaia, Constanța) and the southern area (Agigea, Eforie Sud, Costinești, Olimp, 2 Mai, Vama Veche) in the 2013-2015 and 2018-2020 periods.
The fish caught were immediately refrigerated, packed in ice packs, and transported to the laboratory for measurements. Total length (TL), defined as the distance from the tip of the snout to the tip of the caudal lobes, was measured. Total length was measured to the nearest 0.1 cm and body weight (W) to the nearest 0.1 g. The instrument used to measure length was the ichthyometer, and an electronic scale with increased accuracy was used to determine weight. For some analyses, individuals were grouped into 1 cm length classes.
The length-weight relationship was used to determine the maintenance status of the fish and the type of growth (isometric or allometric). A coefficient b = 3 means linear

isometric growth of the fish (length and weight increase proportionally) (Ricker, 1975).

Statistical processing of the data was performed with the Statistica V12.7 software. First, stake data tables were created, bringing together individual and station codes, geographic coordinates (latitude, longitude), depth zone data, survey regions, sampling year and month, total weight (TW), total length (TL), and the annual variation of the Fulton index (Kn). Normality of data was tested using the Shapiro-Wilk test and homogeneity of variances was tested using the Levene test.

Depending on the results of these tests, parametric Anova or Ancova tests (covariance test) were used to analyse the effect of length separately from the effect of other factors: sex, seasons, years and months, Fisher (F) (if normality and homogeneity of variances were respected) or non-parametric Kruskal-Wallis (for more than two samples, H) or Mann-Whitney (for two samples, Z) tests (if normality or homogeneity of variances were not respected).

Significant tests (F, H or Z) and p-values (probability) have been indicated in the text and figure legends.

Comparison of pairs of values between sexes, stations, years and months was performed using multiple comparison tests of mean ranks or post hoc tests (Newman-Keuls or Bonferonni).

The Fulton index was calculated for the 1200 individuals sampled.

After taking biometric measurements and weighing individuals, the Fulton index (K) was calculated (Beverton & Holt, 1957), according to the following formula:

$K = (W/ l^3) \times 100$, where:

W = weight, in grams;

l = standard length, in cm.

Statistical analyses of individual Fulton index values were performed using STATISTICA 12.7 to analyse differences between sexes, stations, years and months.

RESULTS AND DISCUSSIONS

Distribution of sampled individuals

Trawl samples were collected only from the stations in the northern area i.e.: Gura Portiței, Periboina, Platforme, Corbu, Năvodari Camp, Mamaia and Constanța, and the stationary uncovered pound nets samples were collected from both the north stations: Vadu, Corbu, Camp Năvodari and from the south ones/ stations: Agigea, Eforie, Costinești, Olimp, 2 Mai and Vama Veche.

Of the 1200 individuals analysed, 671 were in the northern area and 529 in the southern area. The highest number of individuals sampled was in Corbu station (270) and the lowest number of individuals analysed was in Mamaia and Olimp stations (Figure 2).

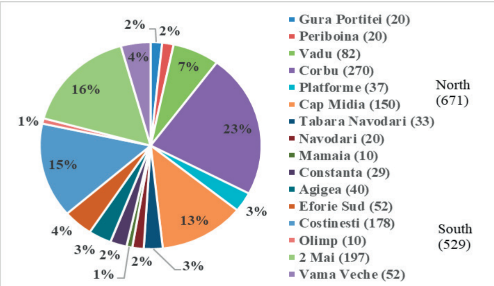

Figure 2. Distribution of sampled individuals per station

Most individuals were sampled in July 2018, the month with the highest number of individuals sampled over the entire study period, which may also be due to the breeding period of the horse mackerel (Figure 3).

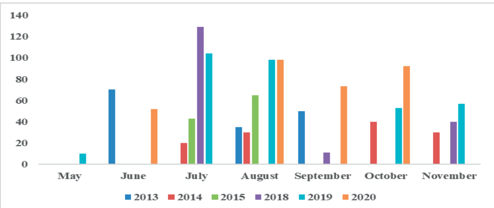

Figure 3. Distribution of individuals analysed by years and months

The lowest number of individuals sampled (10 individuals) was found in May in 2019 and also in September 2018 (11 individuals).

On the Romanian coast, the horse mackerel appears when the water temperature exceeds 13°C, usually in the last decade of May, and remains near the coast until autumn, in November, when the water temperature drops below 14°C.

Total length and total mass of horse mackerel

In this study a number of 1200 individuals were analysed. The average lengths and weights (± standard deviation) were 11.4 ± 2.3 cm and 14.0 ± 8.3 g, respectively, and the minimum and maximum values were 3.0 and 19.0 cm in length and 0.6 and 61.2 g in weight.

Their average lengths and weights were significantly correlated, the relationship between total weight and total length being: $W = 0.0094 \times TL^{2.9485}$, as it results in Figure 4.

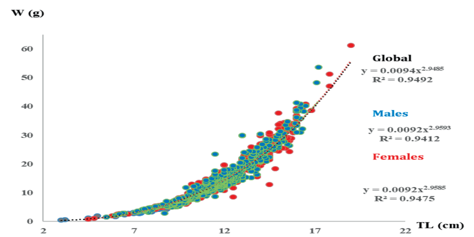

Figure 4. Relationship between total length (TL, cm) and total weight (W, g) in all horse mackerel analysed on the Romanian Black Sea coast in the period 2013-2020, males and females

In the case of horse mackerel individuals analysed for the period 2013-2015 and 2018-2020, the length-weight correlations had positive values. Correlation takes values between 0 and 1 R^2 (0;1) which can be converted to percentage values ($\sqrt{R^2}$).

The value of correlation becomes very important when values can be compared for a larger set of data and over a long period of time. Also, the closer the value of R is to 1, the tighter the correlation is (Fowler et al., 1998).

The length-weight relationship is used to determine the body condition of the fish and the type of growth (isometric or allometric). A coefficient b = 3 signifies linear isometric growth of the fish (length and weight increase proportionally) (Ricker, 1975). Thus, for males the equation is W = 0.0092-TL2.9593 and for females it is W = 0.0092-TL2.9585, thus showing a linear isometric growth pattern, undifferentiated by sex.

The length and total weight of males did not differ significantly from that of females ($p > 0.05$), but juveniles had a mean total length and mean total weight significantly lower than those of males and females (7.5 ± 1.3 cm and respectively 3.4 ± 1.2 g) (H = 146.09; $p < 0.001$ and respectively H = 155.05; $p < 0.001$).

Males and females were grouped as adults (TL = 11.6 ± 2.0 cm) for statistical analyses of spatial (between stations) and temporal variation across years and months.

Overall and for adults, depth of sampling stations from 2018-2020 was not correlated with total length and total weight ($p > 0.05$). For juveniles only, significant negative correlations appear, with larger juvenile individuals of greater size and weight collected at shallower depths (r = -0.38; p = 0.004 and r = -0.52; $p < 0.0001$, respectively).

Spatial variation of total length

Horse mackerel total length varied between stations (H = 160.89; p<0.001). The largest adults (males and females) were sampled at the Olimp station (14.4 ± 1.0 cm) and the smallest at the Năvodari station (9.5 ± 1.5 cm) (H = 140.35; p<0.001) as shown in Figure 5.

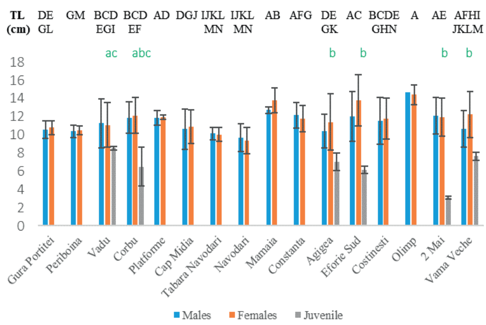

Figure 5. Spatial variation in total length (TL, cm) in adults (males and females) (H = 140.35; $p < 0.001$) and juveniles (H = 45.07; $p < 0.0001$)

Different letters indicate significant differences for adults (upper case) and juveniles (lowercase)

In juveniles, the largest were measured at the Vadu station (8.5 ± 0.2 cm) and the smallest at the 2 Mai station (3.1 ± 0.1 cm) (H = 45.07; $p < 0.0001$).

Annual variation in total length

The total length of horse mackerel showed inter-annual variations (H = 318.81; $p < 0.001$). The largest adults (males and females) were sampled in 2015 (13.8 ± 1.2 cm) and the smallest in 2014 (8.8 ± 1.5 cm) (H = 331.26; $p < 0.001$) as shown in Figure 6.

In juveniles, the largest were measured in 2020 (8.0 ± 0.7 cm) and the smallest in 2013 (3.1 ± 0.1 cm) (H = 331.26; p < 0.001).

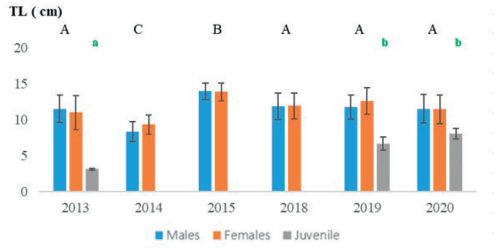

Figure 6. Annual change in total length (TL, cm) in adults (males and females), (H = 331.26; p < 0.001) and juveniles (H = 26.82; p < 0.0001)
Different letters indicate significant differences for adults (upper case) and juveniles (lower case)

Monthly variation of total length

The largest adults (males and females) were sampled in May (13.0 ± 1.0 cm) and the smallest in November (10.4 ± 1.5 cm) (H = 111.51; p < 0.001). In juveniles, the largest were measured in August (7.9 ± 1.2 cm) and the smallest in June (6.5 ± 2.1 cm) (H = 20.36; p < 0, 0001), as result in the Figure 7.

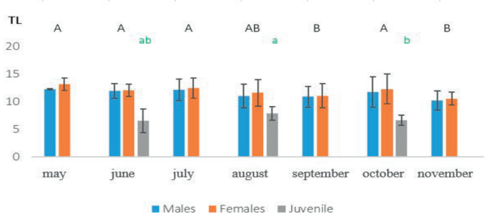

Figure 7. Monthly variation of the total length (TL, cm) in adults (males and females), (H = 111.51; p <0.001) and juveniles (H = 20.36; p <0.0001)
Different letters indicate significant differences for adults (uppercase) and for juveniles(lowercase)

Fulton index of relative body condition

The mean value of the Fulton index (± standard deviation) was 0.84 ± 0.11, and the minimum and maximum values were 0.42 and 1.74. Average length and average weight were significantly correlated with the Fulton index (r = - 0.069; p = 0.017, respectively r = 0.168; p < 0.0001).

The Fulton index in males was not significantly different from females (p > 0.05), but juveniles had a significantly lower index than males and females. (0.82 ± 0.22 cm) (H = 22.68; p < 0.0001). Males and females were regrouped as adults (0.84 ± 0.1 cm) for statistical analyses of spatial (between stations) and temporal variations of the Fulton index by year and month.

Globally, for both adults and juveniles, the depth of sampling stations from 2018-2020 did not correlate with the Fulton index (p > 0.05).

Spatial variation of the Fulton index

The Fulton's index of horse mackerel varied significantly between stations (F = 9.50; p < 0.0001), as shown in Figure 8, and as a function of individual length (F = 19.04; p < 0.0001).

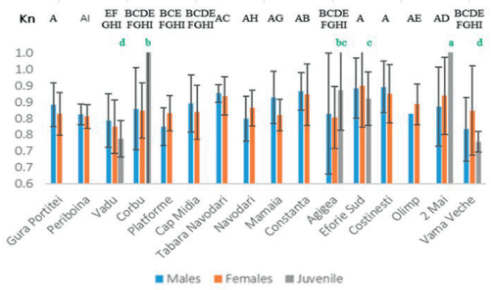

Figure 8. Spatial variation of the Fulton index (K) in adults (males and females),
(F = 7.82; p <0.0001) and juveniles (F = 15.39; p <0.0001)
The different letters indicate significant differences for adults (uppercase) and juveniles (lowercase)

In adults (males and females), the highest values were measured at Eforie station (0.90 ± 0.11) and the lowest at Vadu station (0.78 ± 0.08) (F = 7.82; p < 0.0001). In juveniles, the highest Fulton index values were measured at 2 Mai station (1.74 ± 0.0) and the lowest at Vama Veche station (0.73 ± 0.03) (F = 15.39; p < 0.0001).

Their length also had a significant influence on the value of the Fulton index for both adults (F = 7.66; p = 0.006) and juveniles (F = 41.44; p = 0.0001).

Annual variation of the Fulton index

The Fulton index of horse mackerel showed inter-annual variations (F = 33.73; p < 0.0001), as well as depending on the length of individuals (F = 17.12; p < 0.0001).

In adults (male and female), the highest values were measured in 2018 (0.91 ± 0.09) and the

lowest in 2020 (0.79 ± 0.1) ($F = 32.32$; $p < 0.0001$).
In juveniles, the highest values of the Fulton index were measured in 2013 (1.74 ± 0.0) and the lowest in 2020 (0.75 ± 0.14) ($F = 14.84$; $p < 0.0001$) as shown in Figure 9.

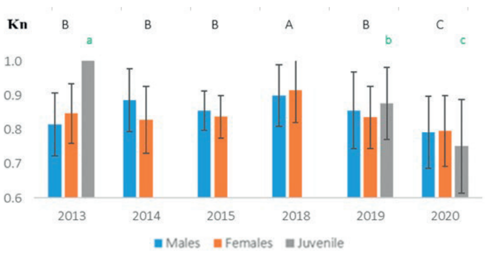

Figure 9. The annual variation of the Fulton index (Kn) in adults (males and females), ($F = 32.32$; $p <0.0001$) and juveniles ($F = 14.84$; $p <0.0001$)
Different letters indicate significant differences for adults (uppercase) and juveniles (lowercase)

Their length also had a significant influence on the value of the Fulton index both for adults ($F = 6.23$; $p = 0.01$) and for juveniles ($F = 28.58$; $p = 0.0001$).

Monthly variation of the Fulton index

The Fulton index of horse mackerel showed variations between months ($F = 23.02$; $p < 0.0001$) as shown in Figure 10, as well as depending on the length of individuals ($F = 19.67$; $p < 0.0001$).
In adults (males and females) the highest values were measured in May (0.94 ± 0.08) and the lowest in June (0.77 ± 0.08) ($F = 26.41$; $p < 0.0001$). In juveniles, the highest Fulton index values were measured in June (1.09 ± 0.64) and the lowest in August (0.78 ± 0.23) ($F = 4.27$; $p < 0.0001$).

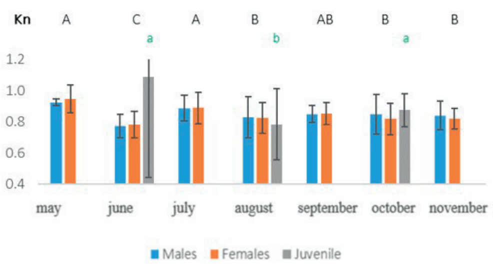

Figure 10. Monthly variation of the Fulton index (Kn) in adults (males and females), ($F = 26.41$; $p <0.0001$) and juveniles ($F = 4.27$; $p <0.02$)

Their length also had a significant influence on the value of the Fulton index for both adults ($F = 11.1$; $p = 0.001$) and juveniles ($F = 124.8$; $p = 0.0001$).
The average lengths and weights (± standard deviation) 11.4 ± 2.3 cm and 14.0 ± 8.3 g, respectively, and the minimum and maximum values 3.0 and 19.0 cm for length and 0.6 and 61.2 g for weight differs from those reported by Yankova & Raykov (2006) from the Bulgarian Black Sea coast (6.5-19 cm, respectively) and by Kasapoglu & Duzgunes (2012), respectively 13.53 ± 0.1 cm for the Black horse mackerel populations from the Turkish Black Sea coast (7.4-14.5 cm), as shown in Table 1.

Table 1. Comparison of average length and weight of horse mackerel with other studies in the Black Sea

References	Zone	Average length (cm)	Average weight (g)
Kasapoglu & Duzgunes, 2012	Black Sea (TR)	13.53 ± 0.1	20.72 ± 3.1
Ozdemir et al., 2015	Black Sea (TR)	13.02±0.02	18.24 ± 0.1
Kasapoglu, 2018	Black Sea (TR)	12..3 ± 2.8	-
Păun et al., 2021	Black Sea (RO)	11.5 ± 2.1	14.3 ± 8.3
Păun et al., 2019b	Black Sea (RO)	12.6 ±0.5	19.12 ± 0.5
The present study	Black Sea (RO)	11.4 ± 2.3	14.0 ± 8.3

However, there were differences in mean length values between investigations. According to Ozaydin et al. (2000), such differences can be attributed to the sampling strategy used, such as the sampling period, as well as temperature variations and likely differences in the trophic potential of the various areas.
Regarding the length-weight relationship, the values of coefficients a and b in other studies from the Black Sea were analysed and compared with those in the present study (Table 2).
The values of coefficient b, for horse mackerel, highlighted in the present study, do not differ significantly ($p > 0.05$) from the values identified in other studies.
Differences in b values can be attributed to one or more factors: season and the effects of different regions, differences in water

temperature and salinity, sex, food availability, differences in the number of specimens examined, as well as in the observed length ranges of the captured species (Goncalves et al., 1997, İşmen et al., 2009, Froese et al., 2011).
In 2019 and 2020, the number of juveniles increased significantly, this may be due to the overexploitation of the horse mackerel stock. A large proportion of immature and juvenile individuals below the optimum catch length (discarded catch) were taken by coastal fishermen from the stock and sold on the market under the counter or destroyed at sea. To eliminate this trend, which is an indicator of increasing overfishing, new fishing methods and management planning for horse mackerel stocks are considered necessary (Daskalov et al., 2012).

Table 2. Values of coefficients a and b in black horse mackerel (comparative analysis)

References	**Zone**	***a***	***b***
Șahin et al., 2009	Black Sea (TR)	0.0089	2.9552
Yankova et al, 2010	Black Sea (BG)	0.0035	3.3046
Yankova et al., 2011	Black Sea (BG)	0.0050	3.1680
Kasapoglu and Düzgüneș, 2012	Black Sea (TR)	0.0060	3.1040
Ozdemir et al., 2015	Black Sea (TR)	0.0057	3.1249
Kasapoglu, 2018	Black Sea (TR)	0.0050	3.138
Păun et al.,2021	Black Sea (RO)	0.0073	3.0546
Păun et al.,2019 b	Black Sea (RO)	0.0121	2.8633
Yankova et al., 2020	Black Sea (BG)	0.078	3.2412
The present study	Black Sea (RO)	0.0094	2.9485

Horse mackerel total length varied between months ($H = 108.79$; $p < 0.001$).
As Borcea (1928) also pointed out, larger specimens of the black horse mackerel, 13-20 cm in length, appear on the Romanian coast in spring; from July, the smaller specimens of 9-12 cm approach the coast, and from August, the youngsters of this species appear.
Similar to the Bulgarian Black Sea coast, Yankova et al. (2020), in their study found that the largest individuals sampled were in June and August (12.5 cm), and the smallest were found in November, their proportion dropping to 9-10 cm, which is due to juvenile individuals aged 0+.
Regarding the Fulton index, Yankova et al. (2020), in their study conducted on the Bulgarian Black Sea coast, found values of the Fulton index K = 0.804-0.828 in the analyzed period 2018-2019.
Yankova (2013), in her study, found that the value of the growth coefficient K increased (0.64 per year). This may probably be due to the average annual water temperature in the Black Sea during summer and partly to the dominance of age 2+ individuals in the catch. The sea surface temperature showed high cooperative values in the range 28-31 degrees Celsius (Roessig et al., 2004).
Sudden changes in temperature can have disastrous effects on fish populations (e.g. heat stress) (Abdulakarim et al., 2005). It is observed that the K value is higher in young (juvenile) fish.

CONCLUSIONS

The average lengths and weights in the present paper differ from those recorded on the Bulgarian and Turkish coast of the Black Sea. Such differences can be attributed to the sampling period as well as to temperature variations and likely differences in the trophic potential of the various areas.
Mean lengths and weights were significantly correlated, with the relationship between total weight and total length being W = 0.0094 x TL2.9485. The b-coefficient values, for horse mackerel, highlighted in the present study did not differ significantly ($p > 0.05$) from the values identified in other studies.
Horse mackerel total length varied between stations and between years and months. The largest adults were sampled at Olimp station and the smallest at Năvodari station. This may be due to the better trophic conditions in the southern area. The largest adults were sampled in 2015 and the smallest in 2014. Looking at the variation between months, we observed that the largest adults were sampled in May, when the horse mackerel approaches the Romanian Black Sea coast and the smallest in November, when it leaves the Romanian coast.

The mean value of the Fulton index in the present study does not differ from the one reported on the Bulgarian Black Sea coast. Average length and weight were significantly correlated with the Fulton index. The Fulton index of males did not differ significantly from that of females ($p > 0.05$). The Fulton index varied significantly between stations, months and years. For adults, the highest values were measured at Eforie station and the lowest at Vadu station, this could probably be due to the greater availability of food in the southern area than in the northern one. The highest values were observed in 2018 and the lowest in 2020. Regarding the monthly variation, we observe that the highest values of the Fulton index were in June, when the reproduction period starts and the lowest in August. Length also had a significant influence on the Fulton index value for both adults and juveniles.

Further research is recommended to improve the knowledge of horse mackerel population dynamics, seasonal migration between river basins (Black Sea, Danube) and influencing factors. There is a need for wider and more open communication between specialists, managers, decision-makers, fishermen, etc. to improve fisheries management.

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REFERENCES

Abdulakarim, M., Bununu, K., & Mohammed, A. (2005). Fish and fisheries of Gubi Dam, Ganjuwa Local Government Area, Bauchi State. *Journal of League of Researchers in Nigeria*, 6(2), 1–4.

Ambroaz, A. (1954). Distribution and fishery of the Black Sea horse mackerel. *Tr.VNIRO*, 28, 113-125 (In Russian).

Bellido, J.M., Pierce, G.J. & Millan M. (2000). Use of frequency analysis methods estimate growth of anchovy in the Gulf of Cadis (SW Spain), *Fisheries Research*, 48, 107-115.

Beverton, R.J.H. & Holt S.J. (1957). On the dynamics of exploited fish populations. *Fishery Investigations*, London Series 2, 19, 1-533.

Borcea, I. (1928). Nouvelles observations sur la faune côtière du littoral roumain de le mer Noire. *Annals. Scient. Univ. Jassy*, 15, 286-298.

Cautis, I. & Ionescu, N. (1979). Structura populatiilor de stavrid. In Editura Pora (ed.), Le Chinchard de la Mer Noire (*Trachurus mediterraneus ponticus*) *Etude monographique, Deuxieme Partie*, 485-508, Institutul Român de Cercetări Marine, Constanța (in Romanian).

Cocan, D. & Mireșan V. (2018). *Ihtiologie, Vol. I, Sistematica și morfologia peștilor*. Cluj-Napoca, RO: Colorama Publishing House (in Romanian).

Craig, J., Thomas M. & Nichols S. (2005). Length-weight relationships and a relative condition factor equation for lake sturgeon (*Acipenser fulvescens*) from the St Clair River system (Michigan, USA). *Journal of Applied Ichtyology*, 21, 81-85.

Daskalov, G., Cardinale, M., Charef, A., Duzgunes, E., Genç, Y., Gümüş, A., Maximov, V., Mikhaylyuk, A., Nikolaev, S., Osio, G. C., Panayotova, M., Radu, G., Raykov, V., Shlyakhov, V., Yankova, M. and Zengin, M., (2012). *JRC Scientific and Policy Reports*. Scientific, Technical and Economic Committee for Fisheries. Assessment of Black Sea Stocks (STECF-12-15). JRC 76532, EUR 25580 EN, ISBN 978-92-79-27208-0, ISSN 1831-9424, doi:10.2788/63715

FAO, (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en.

Fowler, J., Cohen L. & Jarvis P. (1998). Practical Statistics for Field Biology, 2nd Edition, *Wiley*, 131-135.

Froese, R., 2006. Cube Law, condition factor and weight-lenght relationship: history, meta-analysis and recommandations. *Journal of Applied Ichthyology*, 24, 241-253.

Froese, R., Tsikliras A. & Stergiou K. (2011). Editorial note on weight-length relations of fishes. *Acta Ichthyologica et Piscatoria*, 41, 261-263.

Goncalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canárioa, V.M. & Erzini K. (1997). Weight-length relationships for selected fish species of the small-scale demersal fisheries of the South and south-west coast of Portugal. *Fisheries Research*, 30, 253-256.

İşmen, A., Ciğdem Yiğin, C., Altinağac, U. & Ayaz, A. (2009). Length-weight relationships for ten shark species from Saros Bay (North Aegean Sea). *Journal of Applied Ichthyology*, 25, 109-112.

Kasapoglu, N. & Duzgunes E. (2012). The relationship between somatic growth and otholith dimensions of Mediterranean horse mackerel (*Trachurus mediterraneus*) from the Black Sea. *J. Appl. Ichtyol*., 1-4.

Kasapoglu, N. (2018). Age, growth, and mortality of expoited stocks: anchovy, sprat, Mediterranean horse mackerel, whiting, and red mullet in the southestern Black Sea. *Aquat Sci Eng*, 33(2), 39-49.

Nicolae, C. G., Păun, C., Nuță, A.M., Marin, M., Pogurschi, E. & Maftei, M. (2018). Study of the ichtyofauna diversity in the Romanian seaside area. *Current Trend in Natural Science*, 7 (14), 168-175, Pitești;

Ozaydin, O., Bilecenoglu, M. & Kaya M. (2000). Age and growth of the curled picarel centracanthus cirrus Rafinesque, 1810 (Osteichthyes: Centracathidae) in Northern Cyprus, Eastern Mediterranean Sea. *Acta Adriatica*, 41(2), 35-42.

Ozdemir, S., Erdem, E., Ozdemir, Z. & Aksu, H. (2015). Monthly monitoring of lenght-weight relationships of allis shad (*Alosa immaculate* Bennett, 1835), horse mackerel (*Trachurus mediterraneus* Steindachner, 1868) and sprat (*Sprattus sprattus* Linnaeus, 1758) from the Southern Black Sea. Turkey, *Cah. Biol. Mar*., 56, 25-30.

Păun, C., Bănaru, D., Țiganov, G., Galațchi, M., Marin, M., Vidu, L., Nicolae, C. G. (2021). Observation regarding the biology aspects of horse mackerel from romanian coast between 2018-2020, *Scientific Papers, Series D, Animal Science*,. LXIV(2), 479-485.

Păun, C., Galatchi, M., Popescu, A., Vidu, L., Pogurschi, E. & Nicolae, C.G. (2019a). Age at first sexual maturity of *Trachurus Mediterraneus* (Steindachner, 1868) from Romanian Black Sea waters, indicator of good status of the population. *Scientific Papers, Series D. Animal Science*, LXII(2), 371-377.

Păun, C., Galatchi, M., Tiganov, G., Danilov, C., Nicolaev, A., Maximov, V., Nita, V. & Nicolae, C.G. (2019b). Growth and age of *Trachurus mediterraneus* (Steindachner, 1868) on the Romanian Black Sea Coast. *Cercetari Marine – Recherches Marines*, 49(1), 116-124.

Păun, C., Banaru, D., Galatchi, L., Marin, M., Vidu, L. & Nicolae, C.G. (2020). Variation in growth and reproduction measurements of *Trachurus Mediterraneus* from the Romanian Black Sea Coast. *Agrolife Scientific Journal*, 9(2), 212-219.

Prodanov, K., Mikhailov, K., Daskalov, G. M., Maxim, K., Chashchin, A., Arkhipov, A., Shlyakhov, V. & Ozdamar, E. (1997). Environmental management of fish resources in the Black Sea and their national exploitation. *Studies and reviews*. GFCM. 68, FAO, Rome.

Richter, H., Lückstädt, C., Focken, U. & Becker, K. (2000). An improved procedure to assess fish condition on the basis of length-weight relationships. *Archive of Fishery and Marine Research*., 48, 255-264.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191, 209-215.

Roessig, J.M., Woodley, C.M., Cech, J.J. & Hansen, L.J. (2004). Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries*, 14, 251–275.

Șahin, C., Kasapoglu, N., Gözler, A.M., Kalayci, F., Hacimurtazaoğlu, N., & Mutlu, C., (2009). Age, growth, and Gonadosomatic Index (GSI) of Mediterranean Horse Mackerel *Trachurus mediterraneus* (Steindachner, 1868) in the Eastern Black Sea. *Turkish Journal of Zoology*, 33(2), 157-167. https://doi.org/10.3906/zoo-0805-26.

Yankova, M.H. & Raykov, V.S. (2006). Morphological properties of Horse mackerel, *Trachurus mediterraneus ponticus* Aleev, 1956 (Osteichthyes: Carangidae) from the Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, 6, 85-91.

Yankova, M.H., Raykov, V.S., Gerdzhikov, D.B & Frateva, P.B. (2010). Growth and length-weight relationships of the Horse Mackerel, *Trachurus mediterraneus ponticus* (Aleev, 1956), in the Bulgarian Black Sea Coast. *Turkish Journal of Zoology*, 34, 85-92.

Yankova, M., Pavlov, D., Raykov, V., Mihneva, V., & Radu, G. (2011). Length-weight relationships of ten fish species from the Bulgarian Black Sea waters. *Turkish Journal of Zoology, 35*(2), 265-270.

Yankova, M. (2013). Population dynamics of horse mackerel (*Trachurus mediterraneus ponticus*) in the Bulgarian Black Sea Coast, *Hindawi Publishing Corporation, International Scholarly Research Notices*, Article ID 127287, 6 pages, https://doi.org/10.1155/2013/127287.

Yankova, M., Raykov, V., Ivanova, P., Djembekova, N., Valcheva, N., Dechev, D., Hristova, D., Trandafilov, P. & Bacheva, S. (2020). Biological monitoring of landings of commercially important species. *Scientific report covering the results over 2017-2019*, Institute of Oceanology, Fridtjov Nansen, Bulgarian Academy of Sciences.

Yatsu, A. (2019). Review of population dynamics and management of small pelagic fishes around the Japanese Archipelago. *Fish Sci.,* 85, 611–639.