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POPULATION DYNAMICS OF HORSE-MACKEREL (*TRACHURUS MEDITERRANEUS*), AS A VALUABLE ECONOMIC SPECIES FOR THE BULGARIAN BLACK SEA COAST

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Horse-mackerel (*Trachurus mediterraneus* Aleev), is a major commercial fish in the Black Sea waters. This species from the Bulgarian Black Sea pelagic community have been recognized as one of the most ecologically and economically important food resource. Diet composition and feeding intensity of the horse-mackerel, collected on the Bulgarian Black Sea Coast were examined. This study showed that, Crustacea (Copepoda, Cladocera, Mysidacea, Amphipoda, Isopoda, and Decapoda), Polychaeta and Pisces constituted the main prey groups. From investigated prey groups most important for the diet of horse-mackerel are Mysidacea and Pisces, as Mysidacea reached 35% in the stomachs of the size group TL=11 cm and Pisces (*Engraulis engrasicolus* L. and *Sprattus sprattus* L.) accounted for 55.11% in 15 cm size class. Dynamics of the lipids content deposited in the body was investigated. Established percentage of lipids in the body of the horse-mackerel is a good indicator of physiological status of shoals before spawning period and it represents readiness for successful breeding. Catches carried out by both the trawler vessels and trap nets are presented as well. Horse-mackerel has a delicious meat and provides a full meal for the population. The annual consumption in 2008 of fish and fishery products from households grew by an average of 4.6 kilograms per person (4.3 kilograms per person in 2007).

Keywords: Horse-mackerel, commercial species, diet composition, lipids content

1. Introduction

The Black Sea appears to be one of the important fish basins influencing greatly the economy of all the Black Sea countries. Its fish productivity is assessed to be higher as compared to the other seas of the Mediterranean area except the Sea of Azov (Eremeev and Zuyev, 2007).

The small pelagic species Horse-mackerel (*Trachurus mediteraneus*), is of key importance for Bulgarian fisheries for economic reasons, for social reasons (number of fishermen involved) and as livelihood support for population. It represents about 50% of the Bulgarian summer pelagic catches, and a considerable percentage of the Black Sea total catches and plays an important role to provide essential nutrients for the population. The Horse-mackerel (*Trachurus mediterraneus*), is distributed throughout the Black as well as the Mediterranean and Azov Seas. During the warm months of the year is almost widespread on the whole Black Sea coast, where intensively feeds, grows and reproduces. Marine and freshwater fish, which constitute the majority of water products, make up an important part of animal food source for humans (Kandemir and Polat, 2007). Fish are quite different from the other animal food sources, because they provide low-energy and have high-level proteins, which contain all essential amino-acids, so they are beneficial nutrition sources (Weatherley and Gill, 1998). Fish is the primary source of animal protein and of great value in the diet because they provide a good quantity (usually 70 per cent or more) of protein of high biological value, particularly sulphur containing amino acids (Latham, 1997). The present article is intended to shed light on some biological aspects of this valuable economic species in terms of its catches, growth, diet, dynamics of the lipids deposited in the body.

2. Materials and Methods

Samples of horse-mackerel for biological studies were collected monthly, from the Bulgarian Black Sea Coast during April 2007 to October 2008. Of the total 1995 fish examined, 1152 (57.74%) were females and 843(42.26%) were males. Fish samples were caught by gill nets with a mesh size of 6.5 cm. The captured fish were carried immediately on ice to the laboratory for analysis. Total length (TL) was measured to the nearest 0.1cm and body weight to the nearest 0.1 g. The weight was recorded on an electronic balance sensitive to 0.001 g. The specimens for diet study were then preserved in 10% formalin for subsequent analysis. Guts of the specimens were dissected out and analyzed for food components. The food items were identified up to major taxonomic groups. The main food items were identified using the index of relative importance (IRI) of Pinkas et al. (1971), as modified by Hacunda (1981):

$$IRI = \%Fx\ (\%Cn + \%Cw)$$

Statistical differences ($p< 0.05$) in diet composition, with respect to size, was assessed by a chi-square test (Sokal and Rohlf, 1981), applied on the frequency of a given prey. Fat content was determined by a methodology of Krivobok and Tarkovskaya, (1962). In the present study, otoliths were used to determine age. Age was determined from otolith rings as previously described by (Pravdin, 1966). Von Bertalanffy (1938) growth equations were used to describe growth of the species:

$$L_t = L_\infty \{1 - \exp[-k(t - t_0)]\}$$

$$W_t = W_\infty \{1 - \exp[-k(t - t_0)]\}^n$$

where L_t is the total length at age t, L_∞ is the asymptotic total fish length, W_∞ is the asymptotic total weight, K is the growth curvature parameter and coefficient, t_o is the hypothetical age of the fish at zero length. Length-weight relationship of horse-mackerel was estimated by equation: $W= aL^b$ (Ricker, 1975).

Where W is the total body weight (in g) and L is the total length (in cm), a is a coefficient related to the body form and b is an exponent indicating isometric growth when equal to 3. The significance of any difference of population parameters were tested by analysis of variance (ANOVA).

3. Results and Discussion

3.1. Catches

Horse-mackerel (*Trahurus mediterraneus*), plays an important role in the Bulgarian commercial fisheries, the values of its catches varied between 165 t and 179.8 t in the 1992-2008 period (according to official statistics of the National Agency of Fisheries and Aquaculture). The data show considerable fluctuations, they could be distinguished in several stages. In 1992 was achieved a catch of 165 t. Upon 1993 the amounts of catches suddenly dropped particularly in 1994-1999 period, when the landings fluctuated from 8 tons in 1994 to 30 tons in 1999. In the second stage, from 2000 to 2003 years, relatively high amounts of catches are evident. Last relatively high catch amount of 141.6 tons was reported in 2003. For 2005, the catches are low. In 2007 a catch of 56.84 t was achieved. In 2008 substantially increase in catches of horse mackerel was reported, at the level of 179.8 tons (Figure1).

3.2. Length-weight Relationships

Of the total 1995 fish examined, 1152 were females and 843 males. The length- weight relationships of horse-mackerel population in the Bulgarian Black Sea territorial waters were:

For females: $W=0.0038 \cdot L^{3.3029}$ ($r^2 = 0.9100$),

For males: $W=0.0034 \cdot L^{3.3123}$ ($r^2 =0.9235$)

The computed length-weight relationships of males and females of horse-mackerel showed no significant differences in the regressions between sexes according to the analysis of covariance (P>0.05).

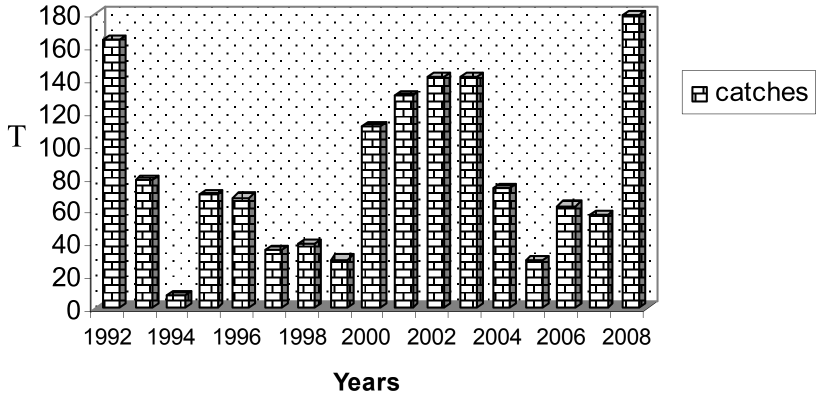

Figure 1. Horse-mackerel catches on the Bulgarian part of the Black Sea (data source NAFA)

The equation given for combined sexes was as following: $W = 0.0035 \cdot L^{3046}$ ($r^2 = 0.9084$). The slope (b - value) of the length- weight relationship was similar for males (3.3123) and females (3.3029), indicating that weight increased allometrically with length. A similar result was reported by Şahin et al., (1997) as 3.2188. However, different results were also reported by (Prodanov et al., 1997, Yankova and Raykov, 2006) as 1.7170 and 1.8644 respectively. These variations could be attributed to differences in age, maturity and sex. Geographic location and associated environmental conditions, such as seasonality, stomach fullness, disease and parasite loads, can also affect the value of b (Bagenal and Tesh, 1978).

3.3. Population parameters

The growth equations for females, males and the total number of samples were the following:

$$L_t = 19.661\{1 - \exp[-0.3075(t + 0.8359)]\} \text{ N=1152}$$

$$L_t = 18.785\{1 - \exp[-0.3373(t + 0.8247)]\} \text{ N=843 and}$$

$$L_t = 19.725\{1 - \exp[-0.3020(t + 0.8305)]\} \text{ N=1995.}$$

During the first three years of life, females and males exhibited different lengths.The differences between observed length was statistically significant between sexes (t-test, P<0.05). The Von Bertalanffy growth parameters calculated using mean total weights are:

$$W_t = 69.676 \quad \{1 - \exp[-0.2994(t + 0.7409)]\}^{3.3029} \quad W_t = 62.037 \quad \{1 - \exp[-0.2940(t + 0.2308)]\}^{3.3123} \text{ and}$$

$$W_t = 71.888 \quad \{1 - \exp[-0.2714(t + 0.5843)]\}^{3.3046}$$

for females, males and respectively, the total. In the present work, growth was estimated for the two sexes separately and the von Bertalanffy parameters were represented in Table 1. The differences for the observed weight were statistically significant between sexes (t-test, P<0.05). The average asymptotic total length values are 19.66(cm) for females and 18.78(cm) for males. The L_∞ value of horse-mackerel population in the Bulgarian Black Sea was calculated as 19.82 (1994-1999 years) and 19.99 (2000-2004 years) in the studies of Yankova and Raykov (2006).

The average asymptotic total weight values are 69.67 for females and 62.03 for males. The theoretical maximum length and weight of females were higher than those of males. According to Weatherly (1972), this may be a result of the faster growth rate of females compared to males, and 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). The value W_∞ calculated in this study for females and males could not be compared with the values of the previously mentioned studies, due to the absence of available data. Differences in growth parameters calculated on data collected at different times, from the same area, could possibly have resulted from annual variations in mean length or weight with age (Avsar, 1995).

Table 1. The growth parameters of horse-mackerel for female, male and both sexes

Gender	L_∞	K year^{-1}	t_o	W_∞	K year^{-1}	t_o	n	N
Females	19.661	0.3075	0.8359	69.676	0.2994	-0.7409	3.3029	1152
Males	18.785	0.3373	0.8247	62.037	0.2940	-0.2308	3.3123	843
Total	19.725	0.3020	0.8305	71.888	0.2714	-0.5843	3.3046	1195

3.4. Horse-mackerel diet

Of the 1042 stomachs of Black Sea horse-mackerel examined, 597 were empty (57.3%). This percentage varied significantly among the size classes, with a maximum of 68.1%-size class 12.5 cm and minimum of 31.9%-size class17.0 cm. The stomach contents of Horse-mackerel (*Trachurus mediterraneus*), consisted of several prey species belonging to the following taxa: Crustacea (Copepoda, Cladocera, Mysidacea, Amphipoda Isopoda, and Decapoda), Polychaetous worms and Pisces. According to the IRI fish *Engraulis encrasicolus* L (IRI=1388.58) and *Sprattus sprattus* (IRI=683.91) were the most frequently consumed prey items, followed by two Mysidacea: *Mesopopsis slabberi (van Beneden)* (IRI= 652.96) *and Paramysis lacustris (Mart)* (IRI= 198.92). Polychaeta *Terebellides stroemi (Sars)* (IRI=281.57) were the most important (IRI) followed by two Copepoda: *Pseudocalanus elongates* (*Beock*) (IRI=127.92) and *Acartia clausi* (*Giesbracht)* (IRI=63.66). Other taxa found in the stomach contents were of lesser importance in the diet. Regarding food in relation to fish size, from investigated prey groups most important for the diet of horse-mackerel are Mysidacea and Pisces (Figure 2), as Mysidacea reached 35% in the stomachs of the size group TL =11cm and Pisces (*Engraulis engrasicolus* L. and *Sprattus sprattus* L.) accounted about 55.11% in 15cm size class.

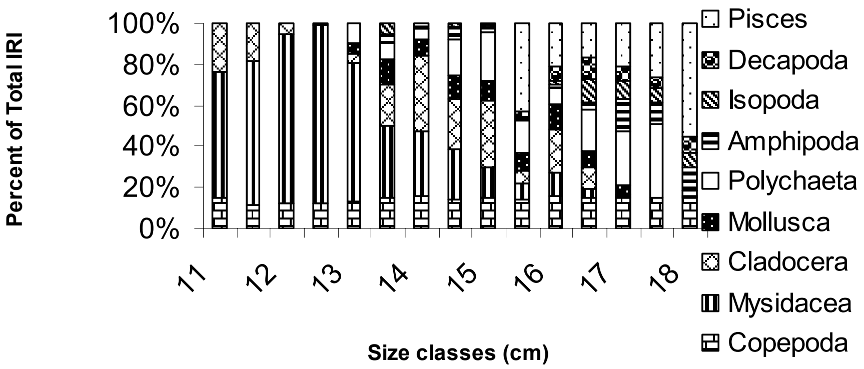

Figure 2. Composition of *Trachurus mediterraneus* diet as a function of size.

The highest differences between the hinges were found in Pisces and Mysidacea, since the box plot (Figure 3) shows relative homogeneity as regards the medians and spreads of rest of the prey groups i.e., contribution of the other groups was comparatively low.

The frequency of Mysidacea ($\chi^2 = 53.4$, $df = 10$, $p = 0.899$) decreased with the increasing of fish linear sizes. The variation of the prey groups in different size classes were as follows: Pisces $\chi^2 = 44.3$, $df = 7$, $p = 0.0001$, Amphipoda: $\chi^2 = 15.6$, $df = 8$, $p = 0.05$; Cladocera: $\chi^2 = 12$, $df = 13$, $p = 0.527$; Mollusca: $\chi^2 = 12$, $df = 9$, $p = 0.196$; Decapoda: $\chi^2 = 5.85$, $df = 8$, $p = 0.664$; Polychaeta: $\chi^2 = 4.18$, $df = 7$, $p = 0.759$; Copepoda $\chi^2 = 1.68$, $df = 13$, $p = 0.999$. Due to high p-values the null hypothesis could be rejected only for Amphipods and Pisces.

The variation of these prey groups in different fish size classes is significantly related to the fish size. The data we obtained in this study show that the main preys of the Black Sea horse-mackerel are fish and zooplankton. This group represents over 55% of the total IRI and was the main food for this species.

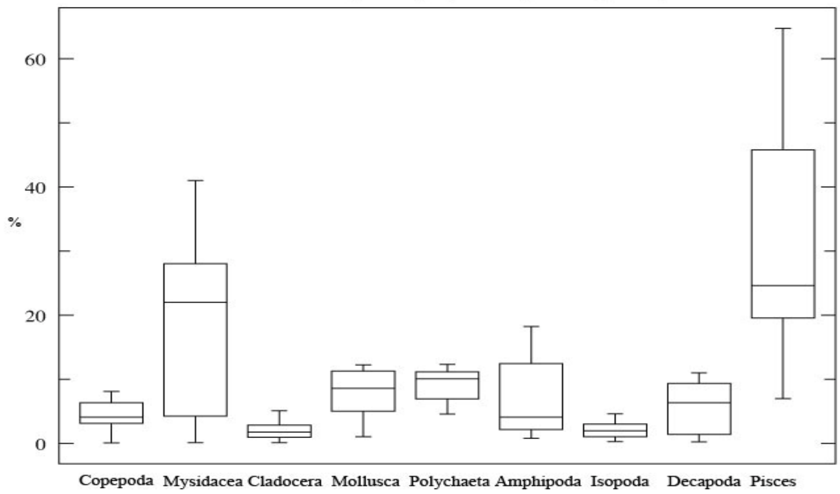

Figure 3. Box plot (median value, 25 - 75 % hinge, minimal and maximal observed percent participation) of the prey items from investigated stomach samples.

3.5. Dynamics of the lipid content

During the year of 2002, horse-mackerel of higher than 7.09% fat-content migrated to the Bulgarian coast. This fact is connected with the case of delay in the process of gonadogenesis. Established percentages of lipids in the body of the horse-mackerel (Trachurus mediterraneus) are a good indicator of physiological status of shoals before the generative period and for their readiness for a successful reproduction. Usually, before the end of June and throughout the mount of July a decrease was noticed in fat contents of 2 to 3.5% i.e., a negative balance of energy resources regarding the maximum of the reproduction season (the breeding season is from May to August). It was in the latter part of the month of July, 2003, after intensive breeding shoal of horse-mackerel showed higher levels than the average fat content of 5.9% (Table 2). Usually, this indicates a dominance of positive over negative balance. With the exceptions of the largest individuals (size classes of 15-16 cm), for which lower lipid percentage levels were found, of 3.6%, resulting from this species being the food base in the area, the upbringing for the this length size was poor. At the end of the second decade of the month of July, 2005 after intensive breeding, shoals of horse-mackerel showed an average fat content (in their body), of 6.38% for the year 2005, and 6.03% for the year 2007. These high values (of fat content in the body of horse-mackerel in the month of July) could occur on food basis availability and a lower common stock of horse-mackerel. It is usually in the month of August that horse-mackerel begins to subside in the reproductive processes, a positive balance, regarding the increase of the intensity of neutral lipids deposit being observed. Twice as high values of fat contents (10.5 %) were recorded in 2004, the month of August, as compared to the same period of 2002.

Significant increases were noticed in the level of neutral lipids, starting from 14.49%, in the month of September and up to 17% in the month of November of the year 2004.

These data are higher than the average perennial values (12%). Such a high amount of neutral lipids registered in the autumn months as an indicator of the higher surviving rate of horse-mackerel in winter period**.** By the end of the month of September, 2004, high-density shoals of horse-mackerel of fat content level (as compared to the average of 14.49%) migrated towards wintering sites becoming a good subject of the trawl fishery in the area. Usually, such quantities of fat content are sufficient in normal wintering to provide energy resources to fish until early spring. During the periods of September to November 2005 we observed increasing levels of neutral lipids from 10.47% (in September) to 10.74% (in November). In October 2005, we established very low levels of lipids of fish body (an average 5.7%) (Table 2), and perhaps this is another horse-mackerel population, which, has not collected enough fat and remained to our coasts for upbreeding. Average data of fat contents (8.98%) for that period are lower, than the perennial values 12% (Figure 4).

Table 2. Long-term data for lipid contents of the Black Sea horse-mackerel

Month. size classes	2003	2004	2005	2006	2007
May, trap nets					
12-13					4.3
13-14					5.4
14-15		3.3		7.3	7.1
15-16		7.5		7.0	5.8
16-17		9.0		4.2	
17-18		8.8		8.0	
18-19		7.2		7.2	
June, trap nets					
9-10			4.4		
10-11		4.5	5.1		
11-12	4.5	4.7	4		1.5
12-13	4.4	2.7	3.9		3.6
13-14	4.4		4.6		3.0
14-15	4.0		5		3.0
15-16	5.2				3.0
July, trap nets					
11-12			6.3		
12-13	5.9		6.1		
13-14	6.2		6.5		4.2
14-15	6.1				6.4
15-16	4.6		6.6		6.1
16-17					7.4
August					
12-13		10.0			
13-14		10.6			
14-15		10.5			
September, fishing vessel					
12-13		12.4	9.6		
13-14		14.5	10.9		
14-15		14.5	10.9		
September, trap nets					
14-15					12.2
15-16					11.1
16-17					11.8
October, fishing vessel					
10-11			5.8		
11-12		14.1	6		
12-13		20.4	5.4		
13-14		14.3			
14-15		11.9			
November, fishing vessel					
12-13			7.3		
13-14			9.2		16.4
14-15		15.0	11.9		13.3
15-16		17.4	15.4		15.5
16-17		18.1	9.9		
17-18		17.9			

The reason is probably accounted for by the generalization of the data for three months leading to a lower general result for the autumn time. Giving up the sample analysis for the month of October will lead to an increased lipid-content level, of 10.61% as for the remaining of the autumn samples - a next to the average value of the perennial data will become appropriate. In September 2007 was established the average amount of lipids deposited in the body of the horse-mackerel of 11.7%. In November 2007, very high levels of body deposited lipids were established, similarly to the levels registered for the year 2004. All this is indicative of the higher rate of survival of horse-mackerel shoals after the winter period and provides us with enough reasons to predict the presence of densely shoals as a good object for trawl fishing.

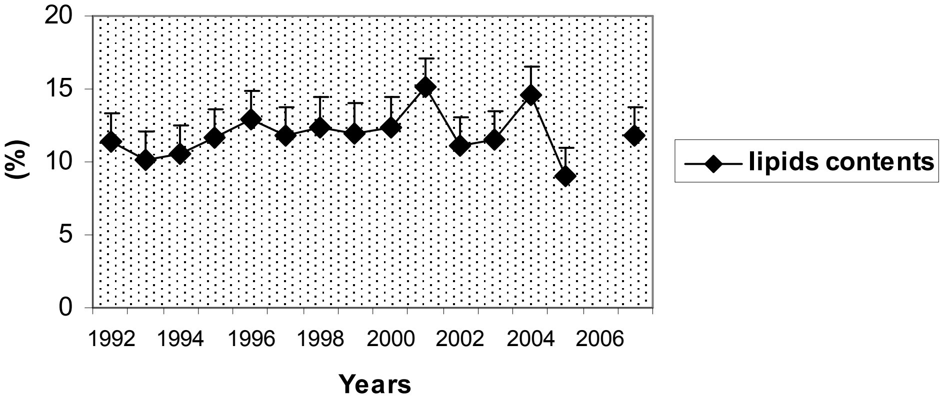

Figure 4. Average data of neutral lipids (%) deposited in the body of the Black Sea horse-mackerel within the periods in September-October 1992-2007.

3.6. Fish consumption

Fish consumption in Bulgaria is lower compared with other maritime states. This is due both to higher prices of some species and the lack of traditions in their regular consumption, despite the dietary and healthy qualities of the fish. Recently, the market offers a wide range of different species often imported at higher prices, which largely contribute to increasing the domestic prices. According to the data from the National Statistical Institute (NSI), in 2008, the annual consumption of fish and fishery products in the households grew by an average of 4.6 kilograms per person (4.3 kilograms per person in 2007). This amount is accounted for by the monitoring of households activities while the data do not include mass feeding consumed amounts.

4. Conclusions

The growth of horse-mackerel in the Bulgarian Black Sea coastal waters is positive allometrically. The theoretical maximum length and weight of females were higher than those of males. The data we obtained in this study show that the main preys of the Black Sea horse-mackerel are fish and zooplankton. This group represents over 55% of the total IRI and was the main food for this species. The amount of total lipids of Horse-mackerel (*Trachurus mediterraneus*), has shown different variations by months and years. Storage lipids vary during reproduction and nutrition periods. The studies showed that the amount of total lipid in fish species reached a maximum level at the end of spawning and during the nutrition season; but that amount diminished during the reproduction season. In August 2004, twice as high values of fat contents of 10.5% were recorded as compared to the same period of 2002. In November 2007, very high levels of lipids deposited in the body of the horse-mackerel were also registered, similarly to the year 2004. All this is indicative of the higher survival from horse-mackerel shoals of the winter period giving us enough reasons to predict the presence of densely shoals as a good object for trawl fishing.

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